MORPHOMETRY OF THE HUMAN FOETUS WITH SPECIAL REFERENCE TO OBSTETRIC DIMENSIONS OF THE HEAD

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MORPHOMETRY OF THE HUMAN FETUS WITH SPECIAL REFERENCE TO THE OBSTETRIC MEASUREMENTS OF THE HEAD

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MORPHOMETRY OF THE HUMAN FETUS WITH SPECIAL REFERENCE TO THE OBSTETRIC MEASUREMENTS OF THE HEAD*

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IT IS a well-recognized fact that present methods of determining the size and body proportions of the fetus *in utero* are distinctly inadequate. Estimation of age from the menstrual history is often as much as four weeks in error, while palpation of the abdomen is hardly more certain. The Mueller maneuver gives valuable information only in certain cases. Roentgenological estimation of the size of the fetal head has been entirely unsuccessful. In short, questions of disproportion between passage and passenger must remain, at present, unanswered while the problems of viability and maturity can be only partially solved. It is the aim of the present research to supply this much-needed information; and it is the purpose of this paper to present, in particular, that part of a study of fetal growth which deals with the obstetric measurements of the head.

In order to compare this series of measurements with other studies of the growth of the fetal head a brief review of the literature on this field is given here. Such related subjects as the measurements of

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the newborn, growth of other parts of the body, and of the body as a whole, will not be included in this discussion.

To Dr. J. Clarke[9] goes the credit of having made the first accurate study of either fetal or newborn heads. He attempted to determine why more stillbirths occurred in male than in female children. His procedure consisted in taking weights, horizontal head circumferences, and an ear to ear measurement over the vertex in 120 newborn children, 60 of each sex. He concluded that the larger head of the male accounted for the higher mortality in that sex.

Since that time many studies of the fetal head have been made, using as a basis for the analysis either body weight, or length of gestation, or both. Of these the more important are Spondli,[49] Pfannkuch,[41] Fehling,[12] Jousset,[26] Arnovljevic,[1] Brandt,[5] Bouillet,[4] Schaeffer,[45] La-Torre,[32] Dardel,[10] Faucon,[11] Weisz,[62] Corrado,[9a] Ballantyne,[2] Legou,[34] Retzius,[42] Friedenthal,[14] Michaelis,[39] Jackson,[24] Lutz,[36] Heuser,[20] Kjölseth,[28] Beneke,[3] and more recently and particularly Streeter.[51]

Pfannkuch[41] noted that the biparietal diameter was always 26.7 to 26.8 per cent of the sum of the biparietal, occipitofrontal and occipitomental diameters of the newborn head. In his own words he states: "Man auf diese Weise eine einfache Formel finden könnte, welche die eine grössere Annäherung an den Terminus *a quo* der Reife gestattet, als die einseitige Verwerthung eines Maasses es ermöglicht."

Probably the two most intensive attempts along this line so far are those of Kjölseth[28] and Corrado.[9a] Unfortunately Kjölseth did not publish her individual measurements and hence her work is not as valuable for the present study as that of Corrado who presented all of his individual readings. Kjölseth made observations upon 250 children born in the Kristiania Klinik. She chose the fourth day of postnatal life as the time to make her measurements. Her analysis was based upon sex of the child and age and parity of the mother; and she, like all other observers recording series of measurements in the literature, did not use body length as a basis for study. Corrado[9a] studied 250 dead fetuses. He used age and sex as a basis.

Jackson[24] has also made a study of head volume increase in fetal life.

Others who published individual head measurements include Spondli,[49] Spiegelberg,[48] Fehling,[12] Jousset,[26] Budin and Ribemont,[7] Faucon,[11] Weisz,[62] Legou,[34] Retzius,[42] Friedenthal,[14] Michaelis,[39] Heuser,[20] and Lutz.[36] These observations will be briefly described here.

Spondli,[49] studied 100 living newborn infants in Zurich.

Spiegelberg[48] measured 53 premature infants in Breslau in connection with a study of newborn measurements.

Jousset[26] published examples of the values of the different diameters for each month of pregnancy. It is not evident that more than one specimen for each month was so studied.

Budin and Ribemont[7] made observations on 39 dead, apparently fresh fetuses, in Paris.

Weisz[62] does not state the number of cases studied. His observations, as well as those of Lutz and Fehling, were based on living newborn fetuses of the last trimester of pregnancy. Lutz[35] measured height, weight, and horizontal head circumference on over 1000 cases in Berlin. Fehling[12] studied horizontal head circumference in 300 newborn infants in Leipzig.

Legou,[34] in Paris, made observations on 106 fetuses of the third to the sixth month.

Retzius[42] studied 48 and Friedenthal[14] 10 preserved specimens. Formalin was employed as preservative in most of Retzius' and in all of Friedenthal's specimens.

Michaelis[39] measured 100 dead, apparently fresh, fetuses.

Heuser[20] in Marburg made a graphic analysis, based on age, of 61 fetuses measured. His graphs are very striking but a close examination of his data indicates such definite results are not justified. By his own statement, he had too few cases from which to draw any definite conclusions.

Calderini[8] made a very extensive study of the bi-parietal and bi-temporal diameters of the fetal head in the last three months of pregnancy. They are, however, published in such a form as to make them impossible of analysis.

Schaeffer[45] published only ranges for the values of the different dimensions in the different months of pregnancy. Neither individual measurements nor definite averages appear in this paper. This makes its value doubtful for the present analysis.

Several attempts to correlate the size and body proportions of the offspring with one, or the other, parent have also appeared in the literature; von Skalowski,[61] Gönner,[15] Heckmann,[18] Weisz,[62] and Riggs.[43] These are very interesting but not convincing. Moreover they deal with the newborn and older infants and do not properly come within the scope of this paper.

Hecker and Jellinghaus[25] found that the fetal head varied considerably in shape, and might, therefore, be very influential in determining the type of presentation. Sergi,[47] Tovo,[56] and Frassetto[13] described changes in the shape of the dried fetal skull at different periods of pregnancy, likening these different shapes to mathematical figures, as ellipsoidal, pentagonal, etc.

Ballantyne[2] was able to collect measurements of three apparently unmoulded heads and deduced therefrom average measurements for

full term fetal heads *in utero*. He also made a study of the effects of birth molding on the different diameters of the head. Other students of the effects of labor on the shape of the fetal head include Swayne,[53] Runge,[44] Stumpf,[52] Mueller,[40] and Kaznelson.[27] Of these, Stumpf has brought out the most comprehensive piece of work, a study of birth molding in 66 cases. He took several measurements of the head at birth and repeated them several days later when the effects of molding had passed off, and yet before any considerable growth had occurred. This work is important, in determining the final condition *in utero*, but needs to be verified by a study of unmoulded heads.

MATERIAL AND METHODS

The material used consisted of some four hundred and fifty preserved human fetuses, from the collections of the Department of Anatomy and the Department of Obstetrics and Gynecology of the School of Medicine of the University of Minnesota. These were first carefully surveyed with the view to making use of only those heads which were not obviously abnormal, either in contour, or in size. It was found that some few specimens had been flattened posteriorly or laterally during preservation, either from too crowded quarters or from some other, less apparent, cause. Moreover, three were obviously hydrocephalic and one microcephalic. Another was acromegalic and another a negro. A few were found to be very soft and, hence, not desirable subjects for anthropometric study. All such undesirable specimens were eliminated, leaving only class A and a few of the class B of Streeter.[51] The selected group numbered three hundred and sixty-nine (369) specimens, ranging from 23 mm. to 544 mm. standing height. It was found that attempts to measure the different diameters and circumferences of specimens below 23 mm. standing height were attended with such a degree of uncertainty as to make the findings of little value. No specimens above 550 mm. standing height were used because of a grave doubt lest they might be distinctly postmature and that they would not represent the usual newborn characteristics. The series included six pairs of twins, and one set of triplets.

These specimens, arranged in groups of 5 cm. intervals, were distributed according to Table I.

All of the fetuses had been preserved in one of two ways. Those specimens which would be satisfactorily hardened in 10 per cent formalin were thus dealt with. A part of those over 30 to 35 centimeters standing height were first injected through the umbilical vein with a 10 per cent solution of formalin containing 1 per cent of chromic acid. The amount injected varied according to necessity in the judgment of the embalmer, Mr. M. Larson. Usually about 30 per cent of the body weight was used. These specimens were then kept in 10 per

TABLE I

DISTRIBUTION OF MATERIAL ACCORDING TO TOTAL LENGTH

Up	to	49	mm.	standing	height—	17	specimens.
50	–	99	"	"	"	—29	"
100	–	149	"	"	"	—45	"
150	–	199	"	"	"	—28	"
200	–	249	"	"	"	—52	"
250	–	299	"	"	"	—46	"
300	–	349	"	"	"	—36	"
350	–	399	"	"	"	—36	"
400	–	449	"	"	"	—29	"
450	–	499	"	"	"	—24	"
500	–	549	"	"	"	—27	"

cent formalin. In order that variability in the effects of preservation might not alter the figures, no specimens were used which had been in the preservative less than six months. Many of them were two or more years in formalin solution.

The instruments used in making the measurements consisted of a steel meter tape, a brass bound wooden meter stick, and a sliding caliper, made of steel and accurately constructed. All of these were calibrated in millimeters and checked with one another very closely. The caliper carried a vernier scale, making possible readings to tenths of a millimeter where desirable. The arms of the caliper had sharp points on one side, flat bars on the other.

The linear measurements were usually taken with the calipers,—the exceptions will be spoken of later. The circumferences were taken with the steel tape except where the readings were 100 mm. or less. In these instances a heavy inelastic linen thread was wound around the part at the proper place, and the overlapping ends cut across with a sharp cataract scissors. The resulting circlet of thread was then measured with the caliper or tape. All readings were recorded in millimeters.

The measurements, taken on each specimen, were ten of the so-called obstetrical measurements of the head, along with the sitting and standing height. In a few of the specimens the lower jaw had previously been removed, thus prohibiting some of the measurements. In a few others some of the distances were not taken because of the presence of an unusually large caput succedanum or for some other, equally good, reason.

The measurements taken, and the technics employed for each were as follows:

1. Sitting height, or crown-rump (C. R.), was taken with the body in an extended attitude (as one would sit erect) with the chin and thighs as nearly as possible at right angles with the body. The readings were taken with the sliding caliper except where the specimens were too long. For these a sliding caliper, in effect, was made from the meter stick, laid parallel to the body and perpendic-

TABLE II
OCCIPITO-FRONTAL-DIAMETER OF HEAD (GLABELLA-INION)
.235 CH (mm) + 4.0 mm (369 cases)

Crown Heel Length (mm)		Crown Rump Length (mm)	Occipito-frontal Diameter (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max.	Min.	Mean (a)	Mean (b)	mm.	Percent		C.H. Length (cm)	Value (mm)	Percent increment
25- 50	37.5	31.4	18	10	13.7	12.7	-1.0	-7.3	17	5	15.75	—
50-100	75.4	57.0	27	14	21.7	21.7	0.0	0.0	29	10	27.50	75
100-150	124.2	88.9	39	26	33.5	33.5	0.0	0.0	45	15	39.25	43
150-200	172.8	119.4	51	38	44.7	44.6	-0.1	-0.2	28	20	51.00	30
200-250	225.3	152.3	68	48	57.9	56.9	-1.0	-1.7	52	25	62.75	23
250-300	272.1	183.9	78	60	69.2	68.6	-0.6	-0.9	46	30	74.50	19
300-350	323.9	222.7	90	71	80.0	80.1	+0.1	+0.1	36	35	86.25	16
350-400	370.6	248.2	101	79	88.8	91.1	+2.3	+2.6	36	40	98.00	13
400-450	423.6	287.9	115	87	99.9	103.5	+3.6	+3.6	29	45	109.75	12
450-500	471.4	318.5	123	99	109.2	114.8	+5.6	+5.1	24	50	122.50	10
500-544	523.4	358.1	129	105	117.2	127.0	+9.8	+8.4	27	55	134.25	9

TABLE III
BI-PARIETAL DIAMETER OF HEAD (MAXIMUM)
.19 CH (mm) + 2.0 mm (369 cases)

Crown Heel Length (mm)		Crown Rump Length (mm)	Bi-Parietal Diameter (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max	Min	Mean (a)	Mean (b)	mm	Per cent		C.H. Length (cm)	Value (mm)	Per cent increment
25- 50	37.5	31.4	12	8	9.5	9.1	-0.4	-4.2	17	5	11.5	—
50-100	75.4	57.0	20	10	16.2	16.3	+0.1	+0.6	29	10	21.0	83
100-150	124.2	88.9	32	21	26.3	25.6	-0.7	-2.7	45	15	30.5	45
150-200	172.8	119.4	41	29	35.5	34.6	-0.7	-2.0	28	20	40.0	31
200-250	225.3	152.3	54	35	45.3	44.8	-0.5	-1.1	52	25	49.5	24
250-300	272.1	183.9	60	43	53.9	53.9	0.0	0.0	46	30	59.0	19
300-350	323.9	222.7	77	52	62.5	63.5	+1.0	+1.6	36	35	68.5	16
350-400	370.6	248.2	78	56	69.6	72.4	+2.8	+4.0	36	40	78.0	14
400-450	423.6	287.9	84	66	77.3	82.4	+5.1	+6.6	29	45	87.5	12
450-500	471.4	318.5	99	70	87.0	91.6	+4.6	+5.3	24	50	97.0	11
500-544	523.4	358.1	102	85	94.0	101.4	+7.4	+7.9	27	55	106.5	10

ular bars applied to it at the proper places. No compression was exercised in taking the readings.

2. Standing height, or crown-heel (C. H.), was found by adding trochanter-to-heel, less trochanter-to-rump to the sitting height, in each case care being exercised to find the center of the trochanter. In those specimens in which it was found impossible to extend the legs on the thighs the trochanter-to-heel measurement was taken in two segments. Trochanter to the center of the lateral surface of the knee joint was first taken, and to this was added the distance from the latter point to the heel. These two measurements were taken uniformly along the right side of the body and were all checked at least once to insure the highest possible degree of accuracy.

3. Head length, or the occipito-frontal diameter (O. F.), was taken from glabella to inion, the longest diameter without respect to the horizontal.

4. Suboccipito-frontal diameter (S. O. F.) was taken from the obstetrical joint (the union of superior and lateral portions of the occipital bone) to the most distant point on the frontal bones.

TABLE IV
SUBOCCIPITO-BREGMATIC DIAMETER OF HEAD
.2 C.H. (MM) + 60 MM (368 CASES)

Crown Heel Length (mm)		Crown Rump Length (mm)	Suboccipito-Bregmatic Diameter (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated				C.H. Length (cm)	Value (mm)	Per cent. increment
Range	Mean		Max.	Min.	Mean (a)	Mean (b)	mm.	Per cent.				
25-50	37.2	31.4	17	9	13.2	13.4	+0.2	+1.5	17	5	160	—
50-100	75.4	57.0	25	16	21.0	21.1	+0.1	+0.5	29	10	260	63
100-150	124.2	88.9	40	24	31.4	30.8	-0.6	-1.9	45	15	360	38
150-200	172.8	119.4	48	37	41.6	40.6	-1.0	-2.4	28	20	460	28
200-250	225.3	152.3	63	43	52.5	51.1	-1.4	-2.7	32	25	560	22
250-300	273.5	184.1	70	51	61.8	60.7	-1.1	-1.8	45	30	660	18
300-350	323.9	222.7	82	62	71.0	70.8	-0.2	-0.3	36	35	760	15
350-400	370.6	248.2	88	67	79.9	80.1	+0.2	+0.3	36	40	860	13
400-450	423.2	287.9	96	78	87.9	90.6	+2.7	+3.1	29	45	960	12
450-500	471.4	318.5	109	83	95.2	100.3	+5.1	+5.4	24	50	1060	10
500-544	523.4	358.1	110	94	102.3	110	+8.4	+8.2	27	55	1160	9

TABLE V
SUBOCCIPITO-FRONTAL DIAMETER OF HEAD
.215 C.H. (MM) + 70 MM (368 CASES)

Crown Heel Length (mm)		Crown Rump Length (mm)	Suboccipito-Frontal Diameter (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated				C.H. Length (cm)	Value (mm)	Per cent. increment
Range	Mean		Max.	Min.	Mean (a)	Mean (b)	mm.	Per cent.				
25-50	37.2	31.4	16	10	14.5	14.9	+0.4	+2.8	17	5	177.5	—
50-100	75.4	57.0	28	15	22.4	23.2	+0.8	+3.6	29	10	285	61
100-150	124.2	88.9	41	25	33.6	33.7	+0.1	+0.3	45	15	392.5	38
150-200	172.8	119.4	50	36	44.8	44.2	-0.6	-1.3	28	20	500.0	27
200-250	225.3	152.3	65	47	56.9	55.4	-1.5	-2.6	32	25	607.5	22
250-300	273.2	184.1	77	56	67.1	65.8	-1.3	-1.9	45	30	715.0	18
300-350	323.9	222.7	87	66	76.3	76.6	+0.3	+0.4	36	35	822.5	15
350-400	370.6	248.2	97	75	85.1	86.7	+1.6	+1.9	36	40	930.0	13
400-450	423.2	287.9	108	82	93.6	98.0	+4.4	+4.7	29	45	1037.5	12
450-500	471.4	318.5	115	89	102.4	108.4	+6.0	+5.9	24	50	1145.0	10
500-544	523.4	358.1	118	99	111.0	119.5	+8.5	+7.7	27	55	1252.5	9

5. Suboccipito-bregmatic diameter (S. O. B.) was found by taking a similar measurement whose second point was the median point of the coronal suture.

6. Occipito-mental diameter (O. M.) was measured from menton to inion.

7. Head width, or bi-parietal diameter (Bi.-P), was always the greatest width of the head above the external auditory meati. This was found, almost always, over the parietal eminences.

8. Horizontal head circumference (H. H. C.) was taken around glabella and inion.

9. Suboccipito-frontal circumference (S. O. F. C.) was taken around the points over which the corresponding diameter was measured.

10. Suboccipito-bregmatic circumference (S. O. B. C.) was also found in a similar manner to the corresponding diameter.

11. Occipital-mental circumference (O. M. C.) was taken around menton and inion.

12. A circumference, designated as "large circumference" (L. C.) was taken around menton and superior tip of occipital bone. This is not the largest cir-

cumference of the head, as Ballantyne[2] and others have shown. It was chosen in preference to the largest circumference because of more definite landmarks, and because of more frequent mention in obstetrics.

A very slight uniform pressure was used in all of the measurements with the idea of entirely avoiding compression, and yet not allowing

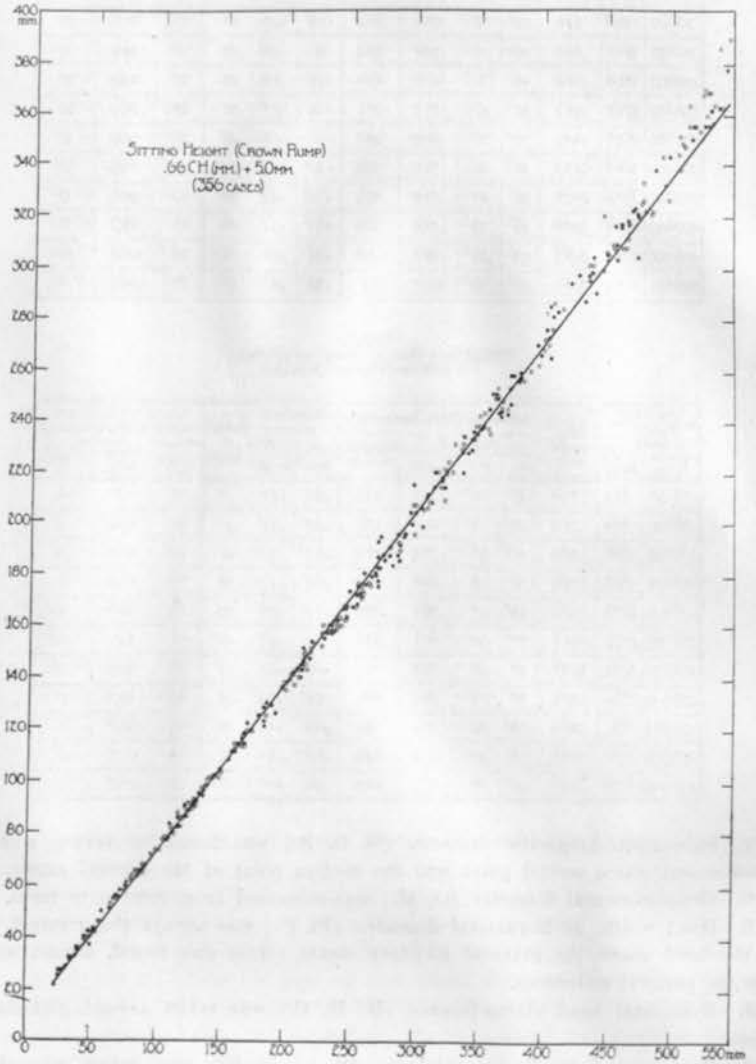

Fig. 1.

to allow the external moisture to evaporate, and yet not long enough to allow any "drying out." The length of time varied, according any slack to be present in the measuring tape. The specimens were also removed from the solutions, long enough previous to measuring, to size, from a few minutes for the smaller ones to nearly an hour for

the larger ones. All measurements were recorded in millimeters, and will so appear in all succeeding tables and figures.

As soon as the series of readings was completed they were assembled and arranged in a table which on account of its length is not published but may be found on file in the Wistar Institute of Anatomy,

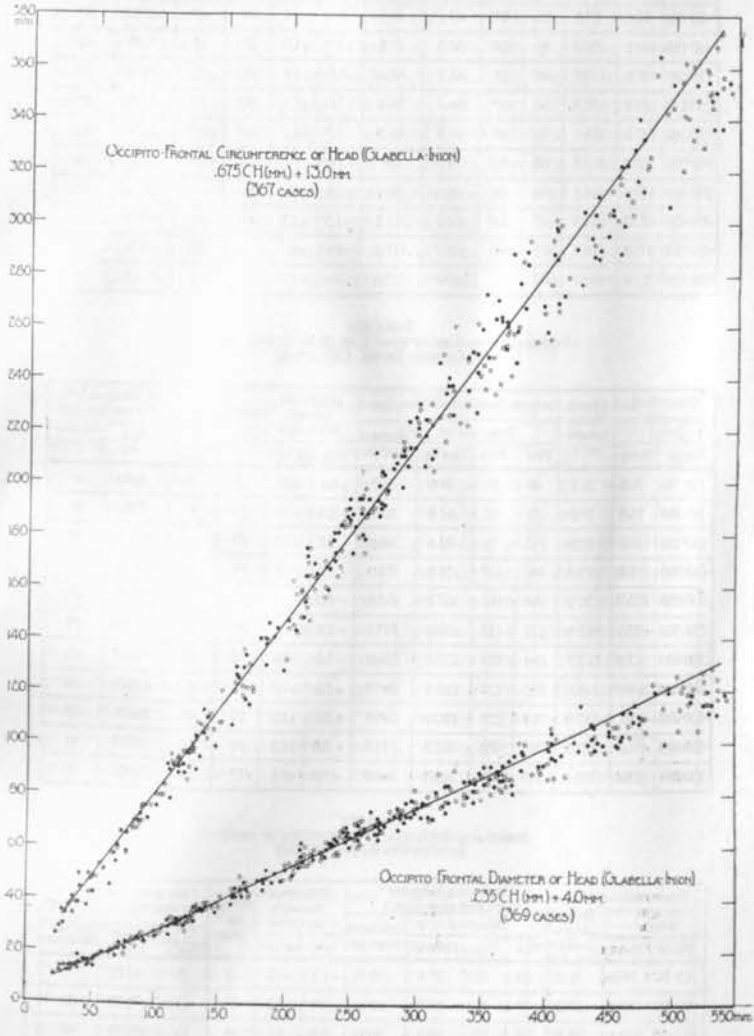

Fig. 2.

of Philadelphia. The amount of variation in the individual measurements was, on the whole, very slight.

The crown rump (C.R.) was then plotted, as ordinate, on coordinate paper, against the crown heel (C.H.), as abscissa. The resulting field graph is shown in Fig. 1. The males are represented by dots, the females by circles. Where the specimens were so small as

TABLE VI

OCCIPITO-MENTAL DIAMETER OF HEAD (MENTON-INION)

.235 C.H.(mm) + 2.0 mm (365 cases)

Crown Heel Length (mm)		Crown Rump Length (mm)	Occipito Mental Diameter (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max.	Min.	Mean (a)	Mean (b)	mm.	Per cent		C.H. Length (cm)	Value (mm)	Per cent increment
25- 50	36.6	30.9	16	8	12.1	10.6	-1.5	-12.4	16	5	13.75	—
50-100	73.4	57.0	25	14	20.1	19.7	-0.4	-2.0	29	10	25.50	85
100-150	124.2	88.9	36	24	30.5	31.2	+0.7	+2.3	45	15	37.25	46
150-200	172.8	119.4	48	37	42.1	42.6	+0.5	+1.2	28	20	49.00	32
200-250	225.3	152.3	66	47	56.1	54.9	-1.2	-2.1	50	25	60.75	24
250-300	273.5	184.1	76	58	67.8	66.3	-1.5	-2.2	45	30	72.50	19
300-350	323.9	223.7	88	70	79.5	78.1	-1.4	-1.8	36	35	84.25	16
350-400	370.6	246.2	104	82	89.6	89.1	-0.5	-0.6	36	40	96.00	14
400-450	423.2	287.9	107	89	100.2	101.5	+1.3	+1.3	29	45	107.75	12
450-500	471.4	318.5	129	103	116.7	117.8	+0.1	+0.1	24	50	119.5	11
500-544	523.4	358.1	142	112	123.4	125.0	+1.6	+1.3	27	55	131.25	10

TABLE VII

OCCIPITO-FRONTAL CIRCUMFERENCE OF HEAD (GLABELLA-INION)

.675 C.H.(mm) + 13.0 mm (367 cases)

Crown Heel Length (mm)		Crown Rump Length (mm)	Horizontal Head Circumference (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max.	Min	Mean (a)	Mean (b)	mm	Per cent		C.H. Length (cm)	Value (mm)	Per cent increment
25- 50	36.6	31.0	49	26	37.5	37.7	+0.2	+0.5	16	5	46.75	—
50-100	73.4	57.0	76	42	61.9	63.9	+2.0	+3.2	29	10	80.50	72
100-150	124.2	88.9	113	76	95.6	96.8	+1.2	+1.3	45	15	114.25	42
150-200	172.8	119.4	146	107	131.8	129.6	-2.2	-1.7	28	20	148.00	30
200-250	225.3	152.3	194	142	167.1	165.1	-2.0	-1.2	50	25	181.75	24
250-300	273.1	183.9	225	173	199.8	197.3	-2.5	-1.3	46	30	215.50	19
300-350	323.9	223.7	261	204	232.6	231.6	-1.0	-0.4	36	35	249.25	16
350-400	369.9	246.2	290	234	260.2	262.7	+2.5	+1.0	35	40	283.00	14
400-450	423.2	287.9	312	255	290.6	298.7	+8.1	+2.8	29	45	316.75	12
450-500	471.4	318.5	364	288	322.9	331.2	+8.3	+2.6	24	50	350.50	11
500-544	523.4	358.1	373	320	348.5	366.3	+17.8	+5.1	27	55	384.25	10

TABLE VIII

SUBOCCIPITO BREGMATIC CIRCUMFERENCE OF HEAD

.625 C.H.(mm) + 16.0 mm (365 cases)

Crown Heel Length (mm)		Crown Rump Length (mm)	Suboccipito Bregmatic Circumference (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max	Min	Mean (a)	Mean (b)	mm	Per cent		C.H. Length (cm)	Value (mm)	Per cent increment
25- 50	36.6	31.0	48	28	37.4	38.9	+1.5	+4.0	16	5	47.25	—
50-100	73.4	57.0	76	41	61.7	63.1	+1.4	+2.3	29	10	78.50	66
100-150	124.1	88.8	110	75	94.6	93.6	-1.0	-1.1	44	15	109.75	40
150-200	172.8	119.4	140	100	124.0	124.0	0.0	0.0	28	20	141.00	28
200-250	225.3	152.3	184	130	160.2	156.8	-3.4	-2.1	52	25	172.25	22
250-300	273.5	184.1	210	161	191.3	186.9	-4.4	-2.3	45	30	203.50	18
300-350	323.9	223.7	247	195	222.2	218.4	-3.8	-1.7	36	35	234.75	15
350-400	369.9	246.2	251	221	248.3	247.2	-1.1	-0.4	35	40	266.00	13
400-450	423.2	287.9	291	246	273.2	280.5	+7.3	+2.7	29	45	297.25	12
450-500	471.4	318.5	352	282	303.8	310.6	+6.8	+2.2	24	50	328.50	11
500-544	523.4	358.1	347	308	336.3	343.1	+6.8	+2.1	27	55	359.75	10

TABLE IX
SUBOCCIPITO-FRONTAL CIRCUMFERENCE OF HEAD
·65 C.H. (mm) + 150 mm (366 cases)

Crown Heel Length (mm)		Crown Rump Length (mm)	Suboccipito-frontal Circumference (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)				C.H. Length (cm)	Value (mm)	Per cent increment
Range	Mean		Max.	Min.	Mean (a)		mm	Per cent				
23-50	36·6	31·0	50	28	39·0	38·8	-0·2	-0·5	16	5	47·5	—
50-100	75·4	57·0	78	45	62·9	64·0	+1·1	+1·7	29	10	80·0	68
100-150	124·2	88·9	115	73	96·8	95·7	-1·1	-1·1	45	15	112·5	41
150-200	172·8	119·4	143	111	132·7	127·3	-5·4	-4·1	28	20	145·0	29
200-250	225·3	152·3	192	141	166·5	161·4	-5·1	-3·1	52	25	177·5	22
250-300	273·5	184·1	224	170	197·7	192·8	-4·9	-2·5	45	30	210·0	18
300-350	323·9	223·7	257	201	227·8	225·5	-2·3	-1·0	36	35	242·5	15
350-400	369·9	248·2	284	225	254·5	255·4	+0·9	+0·4	35	40	275·0	13
400-450	423·2	287·9	300	248	280·3	290·1	+9·8	+3·5	29	45	307·5	12
450-500	471·4	318·5	354	280	312·3	321·4	+9·1	+2·9	24	50	340·0	11
500-544	523·4	356·1	367	319	338·9	355·2	+16·3	+4·8	27	55	372·5	10

TABLE X
OCCIPITO-MENTAL CIRCUMFERENCE OF HEAD (MENTON-INION)
·63 C.H. (mm) + 90 mm (355 cases)

Crown Heel Length (mm)		Crown Rump Length (mm)	Occipito-Mental Circumference (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)				C.H. Length (cm)	Value (mm)	Per cent increment
Range	Mean		Max.	Min.	Mean (a)		mm	Per cent				
23-50	35·9	30·5	47	23	33·4	31·6	-1·8	-5·4	15	5	40·5	—
50-100	75·4	57·0	73	40	53·6	56·5	+2·9	+5·4	29	10	72·0	78
100-150	123·5	88·4	101	63	83·5	86·8	+3·3	+4·0	43	15	103·5	44
150-200	172·8	119·4	135	95	117·5	117·9	+0·4	+0·3	28	20	135·0	30
200-250	225·3	152·3	181	125	156·0	150·9	-5·1	-3·3	50	25	166·5	23
250-300	273·1	183·9	217	162	186·6	181·1	-5·5	-2·9	46	30	198·0	19
300-350	323·9	223·7	257	190	219·8	213·1	-6·7	-3·0	36	35	229·5	16
350-400	369·9	248·2	279	213	245·9	242·0	-3·9	-1·6	35	40	261·0	14
400-450	423·5	288·1	297	230	270·9	275·8	+4·9	+1·8	28	45	292·5	12
450-500	471·5	318·3	367	269	308·4	306·0	-2·4	-0·8	23	50	324·0	11
500-544	525·3	356·4	380	307	336·2	339·9	+3·7	+1·1	22	55	355·5	9

TABLE XI
LARGE CIRCUMFERENCE OF HEAD (MENTON-LAMBDA)
·72 C.H. (mm) + 100 mm (343 cases)

Crown Heel Length (mm)		Crown Rump Length (mm)	Large Circumference (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)				C.H. Length (cm)	Value (mm)	Per cent increment
Range	Mean		Max.	Min.	Mean (a)		mm	Per cent				
23-50	35·9	30·5	46	27	36·7	35·8	-0·9	-2·5	15	5	46·0	—
50-100	75·4	57·0	78	44	62·0	64·3	+2·3	+3·7	29	10	82·0	78
100-150	123·5	88·4	112	79	96·8	98·9	+2·1	+2·2	42	15	118·0	44
150-200	173·2	119·6	153	116	134·6	134·7	+0·1	+0·1	27	20	154·0	31
200-250	225·3	152·3	199	149	174·7	172·2	-2·5	-1·4	50	25	190·0	23
250-300	271·7	182·1	250	182	207·4	205·6	-1·8	-0·9	43	30	226·0	19
300-350	323·9	223·7	282	214	246·1	243·2	-2·9	-1·2	36	35	262·0	16
350-400	369·5	248·6	300	253	276·2	276·0	-0·2	-0·1	33	40	298·0	14
400-450	421·8	286·3	335	278	310·9	313·7	+2·8	+0·9	23	45	334·0	12
450-500	474·0	321·0	402	330	355·3	351·3	-4·0	-1·1	20	50	370·0	11
500-544	523·3	359·2	407	356	383·9	386·8	+2·9	+0·8	25	55	406·0	10

to make the sex indeterminate the symbol ⊗ was used. The grouping of the several points was so close that similar graphs of the other measurements were made, Figs. 2 to 6. In each one, the diameter, or circumference, under consideration was plotted as ordinate, against the crown heel (C. H) as abscissa, and the same plan of distinguishing sex was employed.

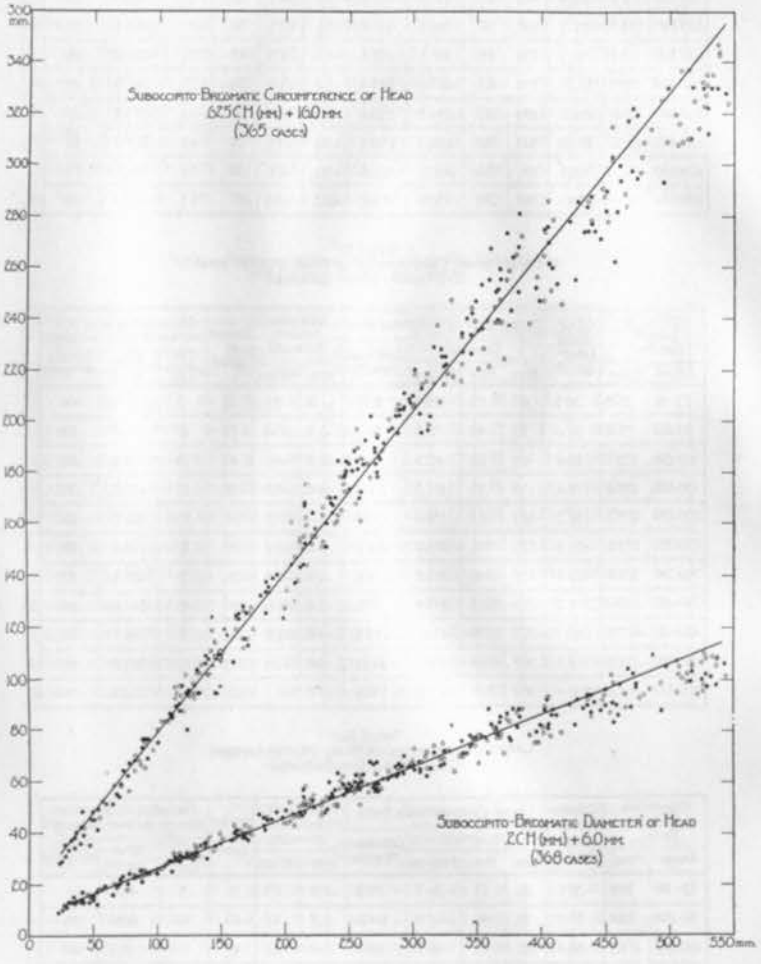

Fig. 3.

It was not at once evident which method of drawing the curves through these graphs would be the most satisfactory. Each of the three most common methods, not including inspection, namely, the weighted median, the weighted average, and the arithmetic average weighted by the median crown-heel height was tried, and equally

satisfactory curves resulted. The method of the averages* was chosen as being the one more commonly used, and, perhaps, the more readily comprehensible.

Fig. 7 with its solid line represents the field graph and resultant

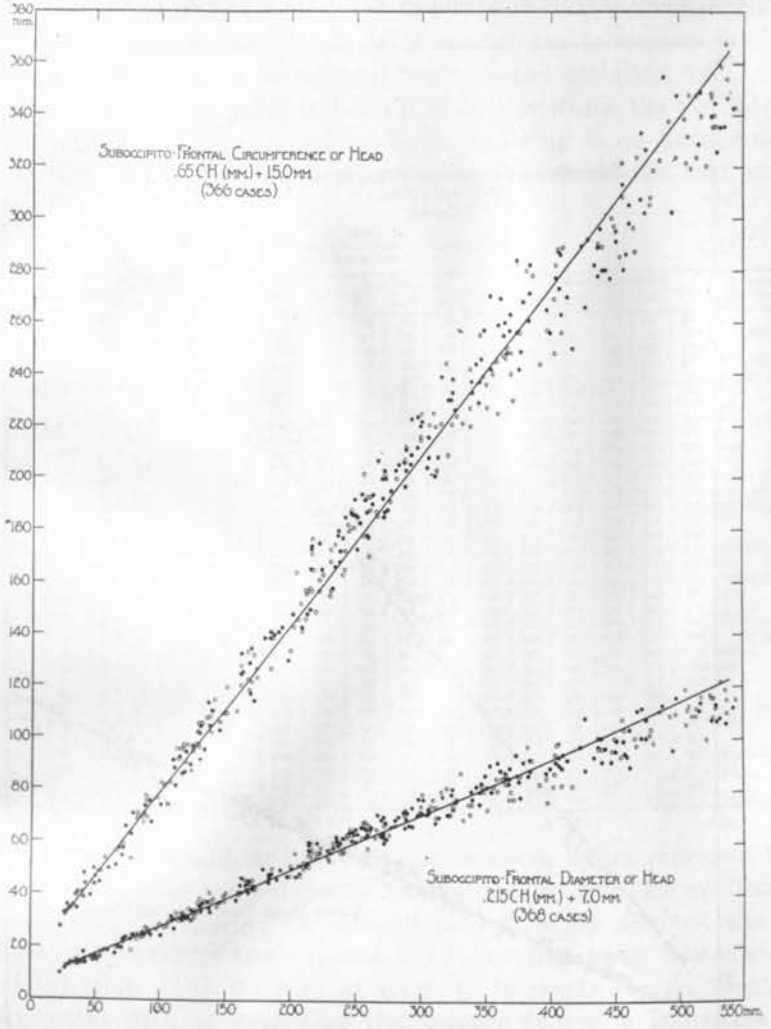

Fig. 4.

curve for the formalin preserved material, and, as such may be taken as quite representative of any series of Caucasian fetuses, similarly preserved. Similar curves resulted for the other measurements studied.

*The arithmetic average, for example, of the occipitofrontal diameters of the cases in each five centimeter interval was plotted against the arithmetic average of the crown heel lengths for the same cases. The curve was drawn through these resulting points.

The data for the plotting of these curves along with the range for the separate intervals, appears in columns 1 to 6 of Tables II to XI.

SUMMARY

These curves were quite striking in their characteristics. The curve for Fig. 5 and the upper graph in Fig. 6 were practically straight lines

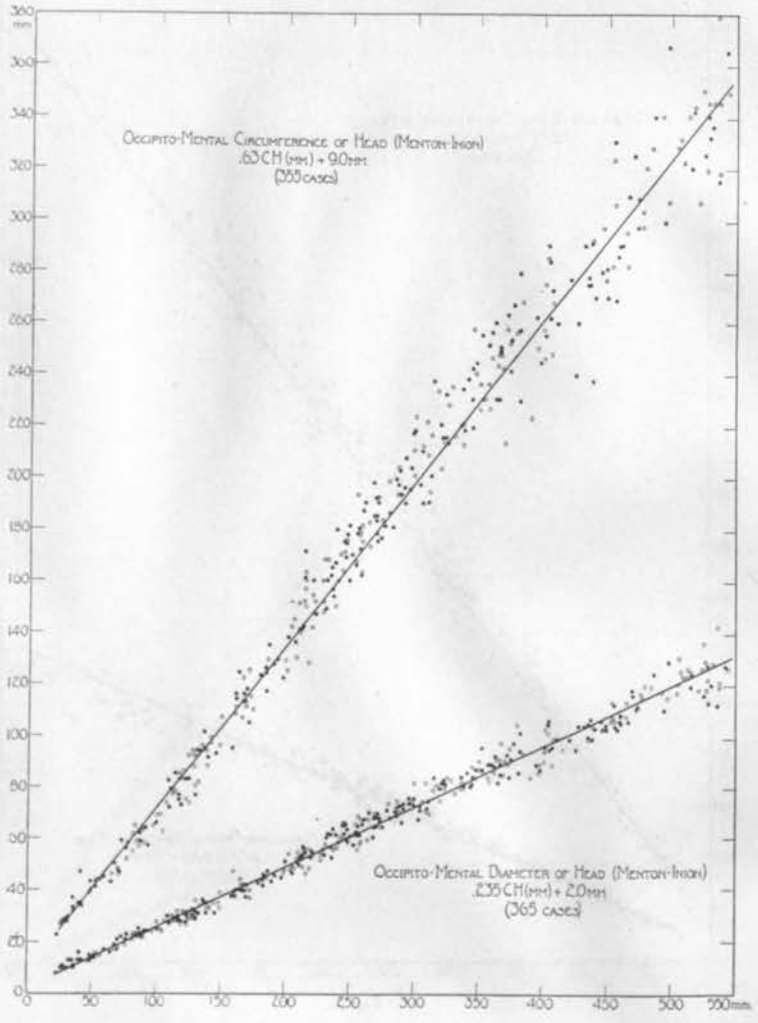

Fig. 5.

throughout. In Fig. 1 there resulted a straight line up to about 300 mm. standing height, at which point there was a deflection toward the vertical. The remaining curves were deflected downward at 300-350 mm. standing height from straight lines below that point. Feeling that these deflections might be artifacts, due to the type of

material, the writer undertook two other sets of investigations to determine:

1. The effects of preservation, as carried out on this material, and
2. The effects of birth moulding.

A chance observation of the injection process suggested the plan to be followed in the first of these two studies. Along with similar changes in the trunk, the cranial vault can be seen to increase in size, as one of these fetuses is injected through the umbilical vein. At the same time, and as a natural result of this swelling, the overriding of the cranial bones produced by birth moulding is, in part, eradicated. One might immediately arrive at the conclusion that such

TABLE XII
MEASUREMENTS OF UNMOULDED HEADS (MM)
(LIVING INFANTS)

Period of Development	Name	Sex	Age in Hours	Parity of Mother	Method of Delivery	Crown Heel Length	Head Diameters					Head Circumferences					Palpable Moulding
							OF	BP	SOB	SOF	OM	HHC	SOBC	SOFC	OMC	LC	
Premature	Be	M	29	?	S.	394	101	79	88	95	96	290	271	277	257	307	None
	Tib	M		?	Post.	396	96	77	88	89	95	272	256	266	246	289	- (Dead)
	Wi	M	28½	I	C.S.	470	111	90	100	103	106	326	305	310	283	330	-
	Br	F	1	VII	S.	475	116	88	96	106	115	324	295	315	295	335	very slight
	We	F	2	1	S.	475	112	87	97	102	100	320	297	307	277	330	Slight transverse
Mature	Pa	F	4	I	S.	480	118	89	95	103	115	338	306	312	310	345	None
	Es	M	6½	IV	C.S.	485	126	103	109	118	117	360	339	348	335	367	-
	McA	M	1½	?	S.	490	124	93	104	113	120	355	320	331	310	360	Slight ant-post
	Fl	F	25½	I	S.	490	122	91	99	110	111	338	307	319	291	355	Slight
	Ca	F	1½	V	S.	490	117	95	102	112	115	334	320	328	310	350	None
	Mo	M	3½	I	S.	490	124	93	105	114	121	361	324	331	280	360	Slight
	Br	M	7	II	C.S.	495	119	94	104	112	124	334	308	327	306	360	None
	Wo	M	3	I	S.	498	122	101	100	112	116	355	330	335	310	358	Slight ant-post
	Bra	M	½	I	S.	500	123	102	97	111	125	365	325	346	333	365	Little ant-post
	Se	F	2	I	S.	500	117	102	107	111	120	347	318	342	322	367	None
	OH	M	7½	V	S.	500	124	93	106	116	119	345	330	334	325	360	
	Oa	M	19½	I	S.	500	118	97	103	109	115	342	319	325	318	358	Slight ant-post
	Or	F	5	?	S.	500	123	101	108	110	125	353	322	328	312	362	None
	Sw	M	10	?	S.	505	114	97	104	112	114	343	326	328	312	354	Slight ant-post
	OC	M	1	II	S.	505	129	97	108	116	116	356	332	340	310	365	None
	Su	F	6½	?	S.	506	125	98	106	122	127	363	339	355	348	377	
	Al	M	6½	IV	S.(t)	510	121	92	105	115	113	347	327	335	302	342	Slight transverse
	As	M	1½	II	S.	510	123	101	102	111	125	358	330	338	335	379	ant-post
	Cl	F	13	I	S.(t)	510	125	98	102	114	121	347	317	335	310	355	None
	Ba	M	23	?	S.(t)	515	128	100	114	120	120	366	342	351	320	373	-
	Fe	F	¾	VI	S.	515	121	98	103	114	120	352	327	340	310	362	-
	Do	M	6½	III	C.S.	520	120	101	104	113	124	357	347	354	305	360	-
	Il	M	4	VI	S.	520	117	102	108	113	115	354	340	348	327	363	Slight ant-post
	En	M	2	I	S.	520	115	91	100	110	116	330	318	325	312	350	None
	Wo	M	21½	V	S.	525	116	94	100	112	117	339	323	334	317	357	
	Ki	M	3½	I	S.	528	132	104	110	115	123	375	345	348	332	384	Slight ant-post
	Gra	F	14	I	S.	535	137	106	119	127	126	385	367	373	320	400	
Average Newborn			6¾			505	122	97	105	114	119	352	328	337	316	368	
Postmature	Re	M	7½	I	S.	570	134	103	109	117	125	365	341	355	322	385	Moderate ant-post

injected fetuses would, at least in some respects, better represent the fetus *in utero* than the uninjected newborn material. This eventually proved to be the case. The detailed plan of study adopted was as follows: (1) measure fresh specimen; (2) measure again immediately after injection. (3) measure at monthly intervals for six months, omitting the fifth, to determine the changes following immersion in formalin. For the smaller fetuses which were not primarily injected, items 1 and 3 were carried out in a similar manner. The results obtained in this latter study on the uninjected specimens were quite significant. For the various measurements the averages obtained are shown in Table XIII.

Preservation by the immersion in formalin alone effects but little change in the dimensions under consideration. The changes noted

are each well within the limit of error in measuring those diameters and can therefore be neglected as far as correcting the curves in Figs. 1 to 6 is concerned. This is particularly true since the size of specimen seemed to bear no relation to the percentage change which oc-

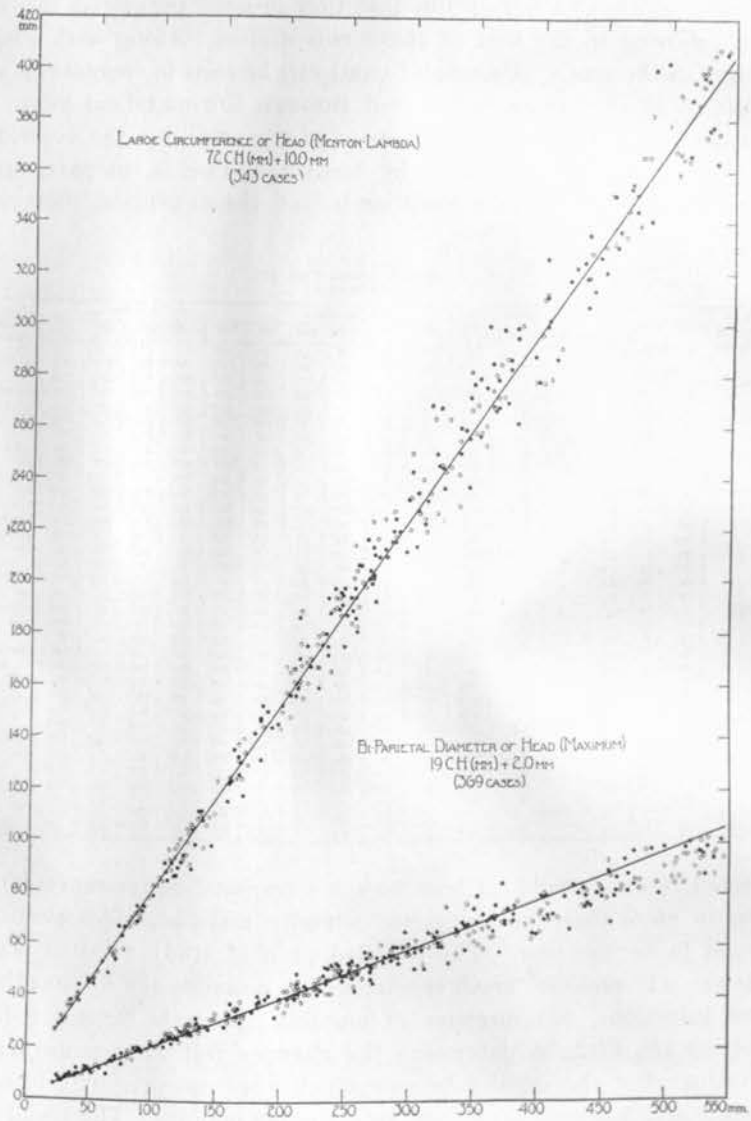

Fig. 6.

curred in that specimen. Only ten fetuses were so studied; but, in view of the almost negative results, such a number of cases is probably sufficient for all practical purposes.

Primary injection, on the other hand, produces a much more notice-

TABLE XIII

	AVERAGE FRESH (MM).	AVERAGE END 6 MOS. (MM)	AVERAGE PER CENT CHANGE
C H	263	261	− 0.8
C R	178	178	− 0.4
O F	65	65	− 1.0
Bi P	49	48	− 0.9
So B	59	60	+ 0.4
S O F	63	64	+ 0.7
O M	62	62	+ 0.1
H H C	183	186	+ 1.4
S O B C	181	184	+ 1.6
S O F C	174	179	+ 2.5
O M C	172	174	+ 1.2
L C	190	190	− 0.3

able change. Here again the immersion, following the injection, produces but little effect. Twenty-six specimens were employed in this study and individual variation, while slightly more marked, was due more to the amount of fluid injected than to any other factor. About 20 per cent of body weight seems to be the optimum amount of fluid to use. The size of the specimens seems to make little, if any, difference in the amount of percentage change produced in the head measurements except that the previous condition, in utero, seems to act as a sort of natural limit to the swelling process. The results of this study are shown in Table XIV.

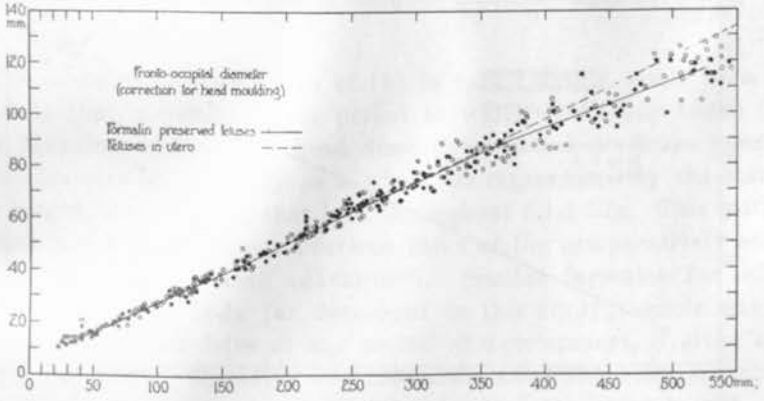

Fig. 7.

While these results show essentially negative changes for body length, they are distinctly positive for the head measurements. If the resulting correction be applied to the original curves for Figs. 1 to 6, the resulting curves would occupy the position shown by the dotted line in Fig. 8. Such a set of curves would properly represent the head proportions for one or several stillborn fetuses.

This injection and preservation study revealed another fact of importance, namely, a peculiar edematous swelling of the tissues of

TABLE XIV

	PERCENTAGE CHANGE FROM INJECTION	PERCENTAGE CHANGE AT END OF 6 MOS. PRESERVATION
C H	+ 1.2	+ 0.8
C R	+ 1.6	+ 0.5
O F	+ 2.6	+ 2.6
Bi P	+ 4.4	+ 3.9
S O B	+ 3.8	+ 3.9
S O F	+ 4.3	+ 4.9
O M	+ 4.8	+ 2.9
H H C	+ 3.8	+ 4.5
S O B C	+ 4.6	+ 4.8
S O F C	+ 5.1	+ 6.1
O M C	+ 7.7	+ 7.4
L C	+ 5.4	+ 5.0

the ischiorectal fossa with a consequent protrusion of the perineum. This protrusion was found to account for the upward deflection in Fig. 1 because the crown-rump measurement had been taken to the perineal surface instead of to the tubera ischii and a technical error thereby introduced. When properly corrected this curve resulted in a straight line, indicated by the straight line in Fig. 1. The fact that injected specimens, in which the effects of birth moulding have been totally or partially obliterated, approach very much more closely to

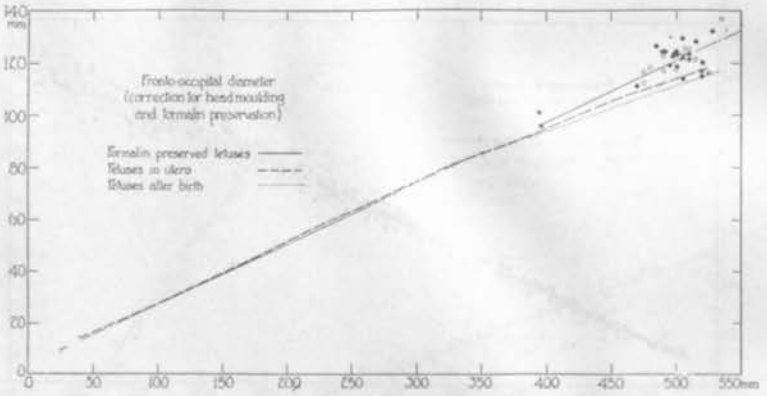

Fig. 8.

a central, straight line than do fresh, stillborn fetuses, suggested the above mentioned study of unmoulded heads. For this purpose babies born by cesarean section, elective, or very early after the initiation of pains, and those born by breech extraction were utilized. Of the total number of these cases (33), twenty-seven were selected as representing full term infants, they having been born within two weeks of term, according to the menstrual history.

The separate readings of this series of measurements appears in

Table XII. These measurements, plotted by the same method outlined above, all fall well above the curve for preserved material (Fig. 8). In fact the average point* of the 27 selected cases, in the case of each dimension, falls directly (within 1 mm.) in the continuation of the lower straight portion of the curve (broken line Fig. 7 and solid line Fig. 8). We have then, by the removal of artifacts, found that all these "curves" are straight lines. These straight lines are shown collectively in Fig. 9 and individually in relation to the field graphs of preserved material in Figs. 1 to 6 inclusive. This would indicate that the fetal head, in relation to body length, has a perfectly definite rate of growth throughout fetal, not including embryonic, life.

These curves, being straight lines, can be expressed by the formula: $y=ax+b$ where (y) is any given measurement, (x) the standing height, and (a) and (b) are constants. For the various measurements these formulae are:

Sitting height	.66	(C H)	+ 5.0 mm
Occipito-Frontal Diameter	.235	"	+ 4.0 "
Biparietal "	.19	"	+ 2.0 "
Suboccipito-Bregmatic "	.2	"	+ 6.0 "
Suboccipito-Frontal "	.215	"	+ 7.0 "
Occipito-Mental "	.235	"	+ 2.0 "
Horizontal Head Circumference	.675	"	+ 13.0 "
Suboccipito-Bregmatic "	.625	"	+ 16.0 "
Suboccipito-Frontal "	.65	"	+ 15.0 "
Occipito-Mental "	.63	"	+ 9.0 "
Large "	.72	"	+ 10.0 "

The constant positive value of (b) in each formula would seem to indicate that, previous to the period at which this study began (23 mm. standing height), the head dimensions gained a certain number of millimeters on the body as a whole, as represented by the standing height, and retained that lead throughout fetal life. This mathematically substantiates our previous ideas of the comparatively early development of the head (Jackson[24]). Similar formulae for other dimensions of the body (as developed in this study) enable one to construct an entire fetus at any period of development, if given any single dimension. Moreover any measurement of the body is just as valuable in determining age as is the standing or sitting height.

From the practical standpoint, one may arrive at the size of the fetal head *in utero* if he can accurately determine the size of any dimension of the body. A moderate number of clinical demonstrations of this indirect method of mensuration have been made and a definite x-ray technic is being developed for this purpose at the present time. Further descriptions of the details of the technic employed and the

*The average values of fetal head measurements *in utero* present a rather new idea of the size and proportions of the obstetric passenger and are probably of more clinical importance, in some respects, than the postnatal values quoted in the text-books.

results obtained will be given when a conclusive series of measurements has been completed.

SUMMARY AND CONCLUSIONS

1. Measurements of the head, *in utero*, plotted as ordinates against standing heights as abscissae for any group of Caucasian fetuses, result

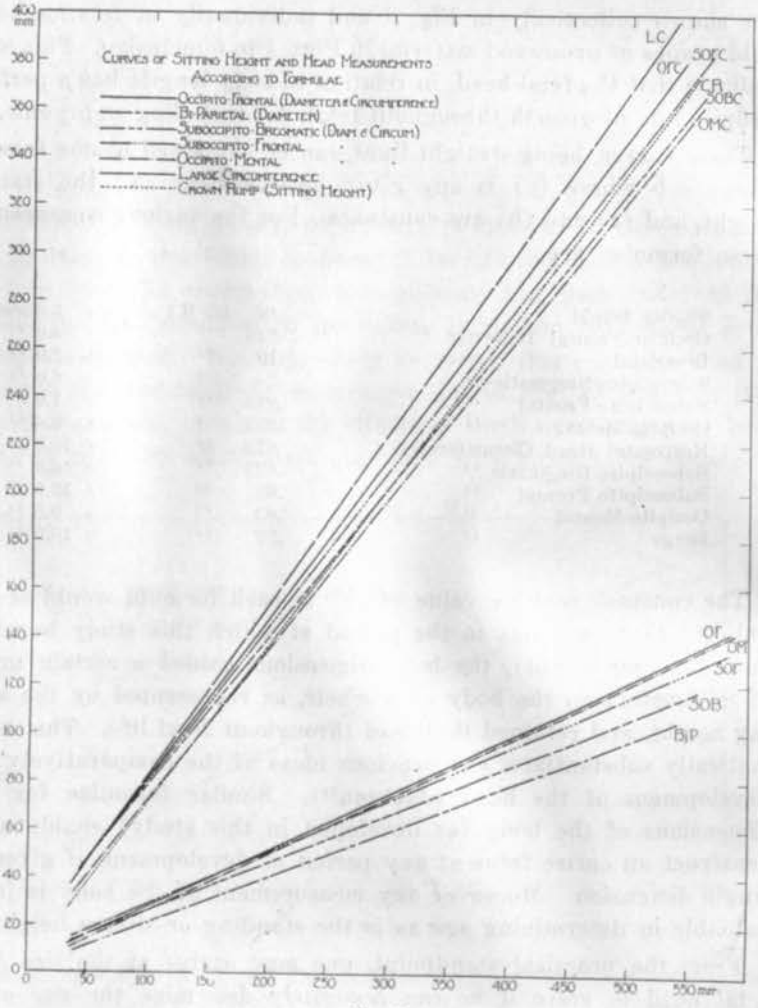

Fig. 9.

in straight line curves. (This is also true of measurements of other parts of the body.)

2. The relationship between any two dimensions can, then, be expressed by the straight-line, empirical formula: $y = ax \pm b$, (x) and (y) being body dimensions, and (a) and (b) constants.

3. By study of these formulae we find definite mathematical proof of development in the cephalocaudad direction during embryonic life and,

4. A definite rate of growth, in any dimension, established by the third month and maintained throughout the remainder of prenatal life.

5. By the aid of these formulae, one may accurately construct the external body proportions of a fetus at any period of development, if given any single dimension.

6. Likewise, one may deduce the size of the head if one can accurately determine any body measurement *in utero*. A definite technic for this indirect intrauterine cephalometry is worthy of prolonged intensive study. By such a method one could solve problems of disproportion between passage and passenger, as well as determine viability and maturity with a considerable degree of accuracy.

7. Birth moulding probably effects greater changes in head dimensions than ordinarily thought.

8. Fetuses preserved in formalin, by the method outlined, better represent the living fetus *in utero* than any other available type of material.

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MORPHOMETRY OF THE HUMAN FOETUS WITH SPECIAL REFERENCE TO OBSTETRIC DIMENSIONS OF THE HEAD

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MORPHOMETRY OF THE HUMAN FETUS WITH SPECIAL REFERENCE TO THE OBSTETRIC MEASUREMENTS OF THE HEAD

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MORPHOMETRY OF THE HUMAN FETUS WITH SPECIAL REFERENCE TO THE OBSTETRIC MEASUREMENTS OF THE HEAD*

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IT IS a well-recognized fact that present methods of determining the size and body proportions of the fetus *in utero* are distinctly inadequate. Estimation of age from the menstrual history is often as much as four weeks in error, while palpation of the abdomen is hardly more certain. The Mueller maneuver gives valuable information only in certain cases. Roentgenological estimation of the size of the fetal head has been entirely unsuccessful. In short, questions of disproportion between passage and passenger must remain, at present, unanswered while the problems of viability and maturity can be only partially solved. It is the aim of the present research to supply this much-needed information; and it is the purpose of this paper to present, in particular, that part of a study of fetal growth which deals with the obstetric measurements of the head.

In order to compare this series of measurements with other studies of the growth of the fetal head a brief review of the literature on this field is given here. Such related subjects as the measurements of

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the newborn, growth of other parts of the body, and of the body as a whole, will not be included in this discussion.

To Dr. J. Clarke[9] goes the credit of having made the first accurate study of either fetal or newborn heads. He attempted to determine why more stillbirths occurred in male than in female children. His procedure consisted in taking weights, horizontal head circumferences, and an ear to ear measurement over the vertex in 120 newborn children, 60 of each sex. He concluded that the larger head of the male accounted for the higher mortality in that sex.

Since that time many studies of the fetal head have been made, using as a basis for the analysis either body weight, or length of gestation, or both. Of these the more important are Spondli,[49] Pfannkuch,[41] Fehling,[12] Jousset,[26] Arnovljevic,[1] Brandt,[5] Bouillet,[4] Schaeffer,[45] La-Torre,[32] Dardel,[10] Faucon,[11] Weisz,[62] Corrado,[9a] Ballantyne,[2] Legou,[34] Retzius,[42] Friedenthal,[14] Michaelis,[39] Jackson,[24] Lutz,[36] Heuser,[20] Kjölseth,[28] Beneke,[3] and more recently and particularly Streeter.[51]

Pfannkuch[41] noted that the biparietal diameter was always 26.7 to 26.8 per cent of the sum of the biparietal, occipitofrontal and occipitomental diameters of the newborn head. In his own words he states: "Man auf diese Weise eine einfache Formel finden könnte, welche die eine grössere Annäherung an den Terminus *a quo* der Reife gestattet, als die einseitige Verwerthung eines Maasses es ermöglicht."

Probably the two most intensive attempts along this line so far are those of Kjölseth[28] and Corrado.[9a] Unfortunately Kjölseth did not publish her individual measurements and hence her work is not as valuable for the present study as that of Corrado who presented all of his individual readings. Kjölseth made observations upon 250 children born in the Kristiania Klinik. She chose the fourth day of postnatal life as the time to make her measurements. Her analysis was based upon sex of the child and age and parity of the mother; and she, like all other observers recording series of measurements in the literature, did not use body length as a basis for study. Corrado[9a] studied 250 dead fetuses. He used age and sex as a basis.

Jackson[24] has also made a study of head volume increase in fetal life.

Others who published individual head measurements include Spondli,[49] Spiegelberg,[48] Fehling,[12] Jousset,[26] Budin and Ribemont,[7] Faucon,[11] Weisz,[62] Legou,[34] Retzius,[42] Friedenthal,[14] Michaelis,[39] Heuser,[20] and Lutz.[36] These observations will be briefly described here.

Spondli,[49] studied 100 living newborn infants in Zurich.

Spiegelberg[48] measured 53 premature infants in Breslau in connection with a study of newborn measurements.

Jousset[26] published examples of the values of the different diameters for each month of pregnancy. It is not evident that more than one specimen for each month was so studied.

Budin and Ribemont[7] made observations on 39 dead, apparently fresh fetuses, in Paris.

Weisz[62] does not state the number of cases studied. His observations, as well as those of Lutz and Fehling, were based on living newborn fetuses of the last trimester of pregnancy. Lutz[35] measured height, weight, and horizontal head circumference on over 1000 cases in Berlin. Fehling[12] studied horizontal head circumference in 300 newborn infants in Leipzig.

Legou,[34] in Paris, made observations on 106 fetuses of the third to the sixth month.

Retzius[42] studied 48 and Friedenthal[14] 10 preserved specimens. Formalin was employed as preservative in most of Retzius' and in all of Friedenthal's specimens.

Michaelis[39] measured 100 dead, apparently fresh, fetuses.

Heuser[20] in Marburg made a graphic analysis, based on age, of 61 fetuses measured. His graphs are very striking but a close examination of his data indicates such definite results are not justified. By his own statement, he had too few cases from which to draw any definite conclusions.

Calderini[8] made a very extensive study of the bi-parietal and bi-temporal diameters of the fetal head in the last three months of pregnancy. They are, however, published in such a form as to make them impossible of analysis.

Schaeffer[45] published only ranges for the values of the different dimensions in the different months of pregnancy. Neither individual measurements nor definite averages appear in this paper. This makes its value doubtful for the present analysis.

Several attempts to correlate the size and body proportions of the offspring with one, or the other, parent have also appeared in the literature; von Skalowski,[61] Gönner,[15] Heckmann,[18] Weisz,[62] and Riggs.[43] These are very interesting but not convincing. Moreover they deal with the newborn and older infants and do not properly come within the scope of this paper.

Hecker and Jellinghaus[25] found that the fetal head varied considerably in shape, and might, therefore, be very influential in determining the type of presentation. Sergi,[47] Tovo,[56] and Frassetto[13] described changes in the shape of the dried fetal skull at different periods of pregnancy, likening these different shapes to mathematical figures, as ellipsoidal, pentagonal, etc.

Ballantyne[2] was able to collect measurements of three apparently unmoulded heads and deduced therefrom average measurements for

full term fetal heads *in utero*. He also made a study of the effects of birth molding on the different diameters of the head. Other students of the effects of labor on the shape of the fetal head include Swayne,[53] Runge,[44] Stumpf,[52] Mueller,[40] and Kaznelson.[27] Of these, Stumpf has brought out the most comprehensive piece of work, a study of birth molding in 66 cases. He took several measurements of the head at birth and repeated them several days later when the effects of molding had passed off, and yet before any considerable growth had occurred. This work is important, in determining the final condition *in utero*, but needs to be verified by a study of unmoulded heads.

MATERIAL AND METHODS

The material used consisted of some four hundred and fifty preserved human fetuses, from the collections of the Department of Anatomy and the Department of Obstetrics and Gynecology of the School of Medicine of the University of Minnesota. These were first carefully surveyed with the view to making use of only those heads which were not obviously abnormal, either in contour, or in size. It was found that some few specimens had been flattened posteriorly or laterally during preservation, either from too crowded quarters or from some other, less apparent, cause. Moreover, three were obviously hydrocephalic and one microcephalic. Another was acromegalic and another a negro. A few were found to be very soft and, hence, not desirable subjects for anthropometric study. All such undesirable specimens were eliminated, leaving only class A and a few of the class B of Streeter.[51] The selected group numbered three hundred and sixty-nine (369) specimens, ranging from 23 mm. to 544 mm. standing height. It was found that attempts to measure the different diameters and circumferences of specimens below 23 mm. standing height were attended with such a degree of uncertainty as to make the findings of little value. No specimens above 550 mm. standing height were used because of a grave doubt lest they might be distinctly postmature and that they would not represent the usual newborn characteristics. The series included six pairs of twins, and one set of triplets.

These specimens, arranged in groups of 5 cm. intervals, were distributed according to Table I.

All of the fetuses had been preserved in one of two ways. Those specimens which would be satisfactorily hardened in 10 per cent formalin were thus dealt with. A part of those over 30 to 35 centimeters standing height were first injected through the umbilical vein with a 10 per cent solution of formalin containing 1 per cent of chromic acid. The amount injected varied according to necessity in the judgment of the embalmer, Mr. M. Larson. Usually about 30 per cent of the body weight was used. These specimens were then kept in 10 per

TABLE I

DISTRIBUTION OF MATERIAL ACCORDING TO TOTAL LENGTH

Up	to	49	mm.	standing	height—	17	specimens.
50	–	99	"	"	"	—29	"
100	–	149	"	"	"	—45	"
150	–	199	"	"	"	—28	"
200	–	249	"	"	"	—52	"
250	–	299	"	"	"	—46	"
300	–	349	"	"	"	—36	"
350	–	399	"	"	"	—36	"
400	–	449	"	"	"	—29	"
450	–	499	"	"	"	—24	"
500	–	549	"	"	"	—27	"

cent formalin. In order that variability in the effects of preservation might not alter the figures, no specimens were used which had been in the preservative less than six months. Many of them were two or more years in formalin solution.

The instruments used in making the measurements consisted of a steel meter tape, a brass bound wooden meter stick, and a sliding caliper, made of steel and accurately constructed. All of these were calibrated in millimeters and checked with one another very closely. The caliper carried a vernier scale, making possible readings to tenths of a millimeter where desirable. The arms of the caliper had sharp points on one side, flat bars on the other.

The linear measurements were usually taken with the calipers,—the exceptions will be spoken of later. The circumferences were taken with the steel tape except where the readings were 100 mm. or less. In these instances a heavy inelastic linen thread was wound around the part at the proper place, and the overlapping ends cut across with a sharp cataract scissors. The resulting circlet of thread was then measured with the caliper or tape. All readings were recorded in millimeters.

The measurements, taken on each specimen, were ten of the so-called obstetrical measurements of the head, along with the sitting and standing height. In a few of the specimens the lower jaw had previously been removed, thus prohibiting some of the measurements. In a few others some of the distances were not taken because of the presence of an unusually large caput succedanum or for some other, equally good, reason.

The measurements taken, and the technics employed for each were as follows:

1. Sitting height, or crown-rump (C. R.), was taken with the body in an extended attitude (as one would sit erect) with the chin and thighs as nearly as possible at right angles with the body. The readings were taken with the sliding caliper except where the specimens were too long. For these a sliding caliper, in effect, was made from the meter stick, laid parallel to the body and perpendic-

TABLE II
OCCIPITO-FRONTAL-DIAMETER OF HEAD (GLABELLA-INION)
.235 CH (mm) + 4.0 mm (369 cases)

Crown Heel Length (mm)		Crown Rump Length (mm)	Occipito-frontal Diameter (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max.	Min.	Mean (a)	Mean (b)	mm.	Percent		C.H. Length (cm)	Value (mm)	Percent increment
25- 50	37.5	31.4	18	10	13.7	12.7	-1.0	-7.3	17	5	15.75	—
50-100	75.4	57.0	27	14	21.7	21.7	0.0	0.0	29	10	27.50	75
100-150	124.2	88.9	39	26	33.5	33.5	0.0	0.0	45	15	39.25	43
150-200	172.8	119.4	51	38	44.7	44.6	-0.1	-0.2	28	20	51.00	30
200-250	225.3	152.3	68	48	57.9	56.9	-1.0	-1.7	52	25	62.75	23
250-300	272.1	183.9	78	60	69.2	68.6	-0.6	-0.9	46	30	74.50	19
300-350	323.9	222.7	90	71	80.0	80.1	+0.1	+0.1	36	35	86.25	16
350-400	370.6	248.2	101	79	88.8	91.1	+2.3	+2.6	36	40	98.00	13
400-450	423.6	287.9	115	87	99.9	103.5	+3.6	+3.6	29	45	109.75	12
450-500	471.4	318.5	123	99	109.2	114.8	+5.6	+5.1	24	50	122.50	10
500-544	523.4	358.1	129	105	117.2	127.0	+9.8	+8.4	27	55	134.25	9

TABLE III
BI-PARIETAL DIAMETER OF HEAD (MAXIMUM)
.19 CH (mm) + 2.0 mm (369 cases)

Crown Heel Length (mm)		Crown Rump Length (mm)	Bi-Parietal Diameter (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max	Min	Mean (a)	Mean (b)	mm	Per cent		C.H. Length (cm)	Value (mm)	Per cent increment
25- 50	37.5	31.4	12	8	9.5	9.1	-0.4	-4.2	17	5	11.5	—
50-100	75.4	57.0	20	10	16.2	16.3	+0.1	+0.6	29	10	21.0	83
100-150	124.2	88.9	32	21	26.3	25.6	-0.7	-2.7	45	15	30.5	45
150-200	172.8	119.4	41	29	35.5	34.6	-0.7	-2.0	28	20	40.0	31
200-250	225.3	152.3	54	35	45.3	44.8	-0.5	-1.1	52	25	49.5	24
250-300	272.1	183.9	60	43	53.9	53.9	0.0	0.0	46	30	59.0	19
300-350	323.9	222.7	77	52	62.5	63.5	+1.0	+1.6	36	35	68.5	16
350-400	370.6	248.2	78	56	69.6	72.4	+2.8	+4.0	36	40	78.0	14
400-450	423.6	287.9	84	66	77.3	82.4	+5.1	+6.6	29	45	87.5	12
450-500	471.4	318.5	99	70	87.0	91.6	+4.6	+5.3	24	50	97.0	11
500-544	523.4	358.1	102	85	94.0	101.4	+7.4	+7.9	27	55	106.5	10

ular bars applied to it at the proper places. No compression was exercised in taking the readings.

2. Standing height, or crown-heel (C. H.), was found by adding trochanter-to-heel, less trochanter-to-rump to the sitting height, in each case care being exercised to find the center of the trochanter. In those specimens in which it was found impossible to extend the legs on the thighs the trochanter-to-heel measurement was taken in two segments. Trochanter to the center of the lateral surface of the knee joint was first taken, and to this was added the distance from the latter point to the heel. These two measurements were taken uniformly along the right side of the body and were all checked at least once to insure the highest possible degree of accuracy.

3. Head length, or the occipito-frontal diameter (O. F.), was taken from glabella to inion, the longest diameter without respect to the horizontal.

4. Suboccipito-frontal diameter (S. O. F.) was taken from the obstetrical joint (the union of superior and lateral portions of the occipital bone) to the most distant point on the frontal bones.

TABLE IV
SUBOCCIPITO-BREGMATIC DIAMETER OF HEAD
.2 C.H. (MM) + 60 MM (368 CASES)

Crown Heel Length (mm)		Crown Rump Length (mm)	Suboccipito-Bregmatic Diameter (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated				C.H. Length (cm)	Value (mm)	Per cent. increment
Range	Mean		Max.	Min.	Mean (a)	Mean (b)	mm.	Per cent.				
25-50	37.2	31.4	17	9	13.2	13.4	+0.2	+1.5	17	5	160	—
50-100	75.4	57.0	25	16	21.0	21.1	+0.1	+0.5	29	10	260	63
100-150	124.2	88.9	40	24	31.4	30.8	-0.6	-1.9	45	15	360	38
150-200	172.8	119.4	48	37	41.6	40.6	-1.0	-2.4	28	20	460	28
200-250	225.3	152.3	63	43	52.5	51.1	-1.4	-2.7	32	25	560	22
250-300	273.5	184.1	70	51	61.8	60.7	-1.1	-1.8	45	30	660	18
300-350	323.9	222.7	82	62	71.0	70.8	-0.2	-0.3	36	35	760	15
350-400	370.6	248.2	88	67	79.9	80.1	+0.2	+0.3	36	40	860	13
400-450	423.2	287.9	96	78	87.9	90.6	+2.7	+3.1	29	45	960	12
450-500	471.4	318.5	109	83	95.2	100.3	+5.1	+5.4	24	50	1060	10
500-544	523.4	358.1	110	94	102.3	110	+8.4	+8.2	27	55	1160	9

TABLE V
SUBOCCIPITO-FRONTAL DIAMETER OF HEAD
.215 C.H. (MM) + 70 MM (368 CASES)

Crown Heel Length (mm)		Crown Rump Length (mm)	Suboccipito-Frontal Diameter (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated				C.H. Length (cm)	Value (mm)	Per cent. increment
Range	Mean		Max.	Min.	Mean (a)	Mean (b)	mm.	Per cent.				
25-50	37.2	31.4	16	10	14.5	14.9	+0.4	+2.8	17	5	177.5	—
50-100	75.4	57.0	28	15	22.4	23.2	+0.8	+3.6	29	10	285	61
100-150	124.2	88.9	41	25	33.6	33.7	+0.1	+0.3	45	15	392.5	38
150-200	172.8	119.4	50	36	44.8	44.2	-0.6	-1.3	28	20	500.0	27
200-250	225.3	152.3	65	47	56.9	55.4	-1.5	-2.6	32	25	607.5	22
250-300	273.2	184.1	77	56	67.1	65.8	-1.3	-1.9	45	30	715.0	18
300-350	323.9	222.7	87	66	76.3	76.6	+0.3	+0.4	36	35	822.5	15
350-400	370.6	248.2	97	75	85.1	86.7	+1.6	+1.9	36	40	930.0	13
400-450	423.2	287.9	108	82	93.6	98.0	+4.4	+4.7	29	45	1037.5	12
450-500	471.4	318.5	115	89	102.4	108.4	+6.0	+5.9	24	50	1145.0	10
500-544	523.4	358.1	118	99	111.0	119.5	+8.5	+7.7	27	55	1252.5	9

5. Suboccipito-bregmatic diameter (S. O. B.) was found by taking a similar measurement whose second point was the median point of the coronal suture.

6. Occipito-mental diameter (O. M.) was measured from menton to inion.

7. Head width, or bi-parietal diameter (Bi.-P), was always the greatest width of the head above the external auditory meati. This was found, almost always, over the parietal eminences.

8. Horizontal head circumference (H. H. C.) was taken around glabella and inion.

9. Suboccipito-frontal circumference (S. O. F. C.) was taken around the points over which the corresponding diameter was measured.

10. Suboccipito-bregmatic circumference (S. O. B. C.) was also found in a similar manner to the corresponding diameter.

11. Occipital-mental circumference (O. M. C.) was taken around menton and inion.

12. A circumference, designated as "large circumference" (L. C.) was taken around menton and superior tip of occipital bone. This is not the largest cir-

cumference of the head, as Ballantyne[2] and others have shown. It was chosen in preference to the largest circumference because of more definite landmarks, and because of more frequent mention in obstetrics.

A very slight uniform pressure was used in all of the measurements with the idea of entirely avoiding compression, and yet not allowing

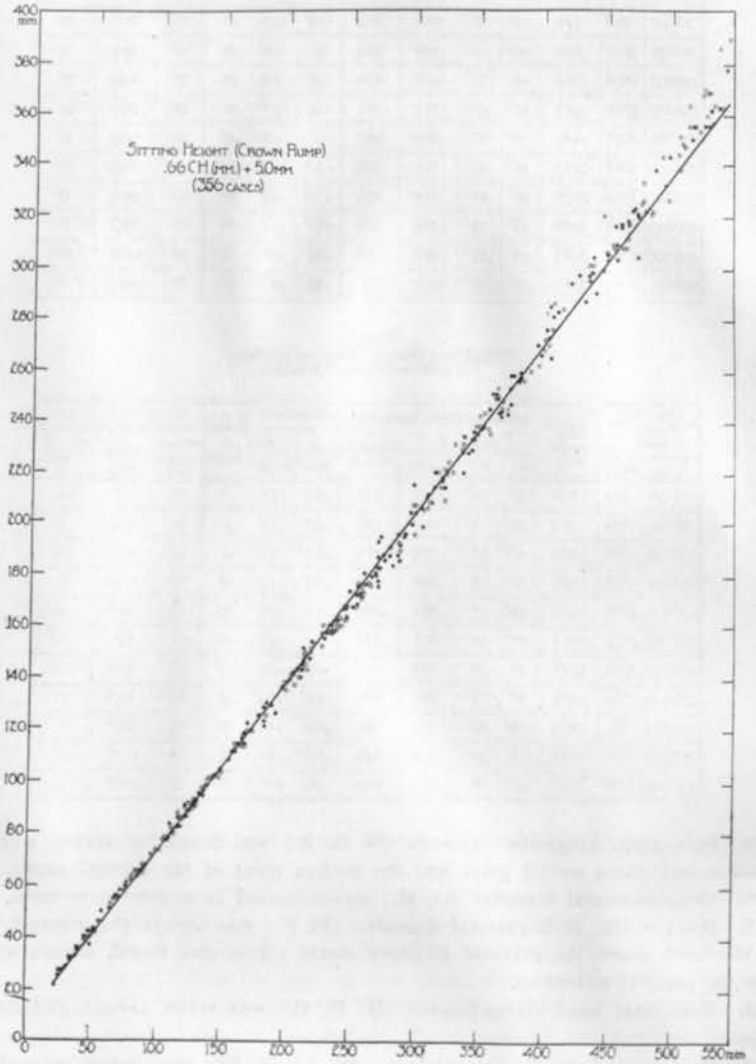

Fig. 1.

to allow the external moisture to evaporate, and yet not long enough to allow any "drying out." The length of time varied, according any slack to be present in the measuring tape. The specimens were also removed from the solutions, long enough previous to measuring, to size, from a few minutes for the smaller ones to nearly an hour for

the larger ones. All measurements were recorded in millimeters, and will so appear in all succeeding tables and figures.

As soon as the series of readings was completed they were assembled and arranged in a table which on account of its length is not published but may be found on file in the Wistar Institute of Anatomy,

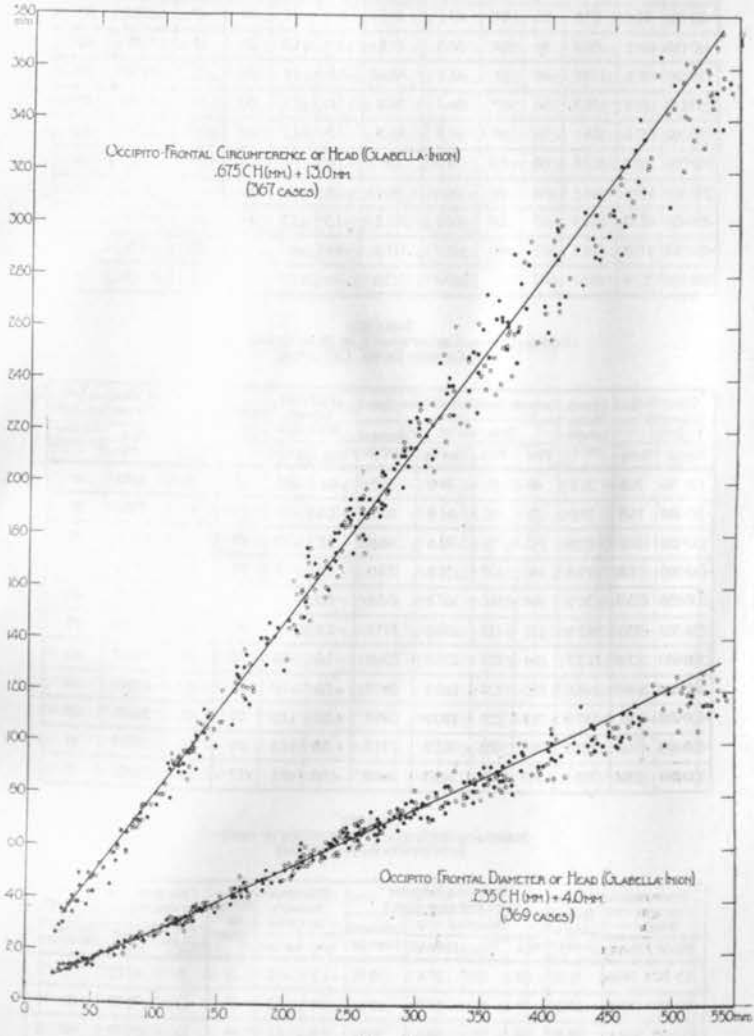

Fig. 2.

of Philadelphia. The amount of variation in the individual measurements was, on the whole, very slight.

The crown rump (C.R.) was then plotted, as ordinate, on coordinate paper, against the crown heel (C.H.), as abscissa. The resulting field graph is shown in Fig. 1. The males are represented by dots, the females by circles. Where the specimens were so small as

TABLE VI

OCCIPITO-MENTAL DIAMETER OF HEAD (MENTON-INION)

.235 C.H.(mm) + 2.0 mm (365 cases)

Crown Heel Length (mm)		Crown Rump Length (mm)	Occipito Mental Diameter (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max.	Min.	Mean (a)	Mean (b)	mm.	Per cent		C.H. Length (cm)	Value (mm)	Per cent increment
25- 50	36.6	30.9	16	8	12.1	10.6	-1.5	-12.4	16	5	13.75	—
50-100	73.4	57.0	25	14	20.1	19.7	-0.4	-2.0	29	10	25.50	85
100-150	124.2	88.9	36	24	30.5	31.2	+0.7	+2.3	45	15	37.25	46
150-200	172.8	119.4	48	37	42.1	42.6	+0.5	+1.2	28	20	49.00	32
200-250	225.3	152.3	66	47	56.1	54.9	-1.2	-2.1	50	25	60.75	24
250-300	273.5	184.1	76	58	67.8	66.3	-1.5	-2.2	45	30	72.50	19
300-350	323.9	223.7	88	70	79.5	78.1	-1.4	-1.8	36	35	84.25	16
350-400	370.6	246.2	104	82	89.6	89.1	-0.5	-0.6	36	40	96.00	14
400-450	423.2	287.9	107	89	100.2	101.5	+1.3	+1.3	29	45	107.75	12
450-500	471.4	318.5	129	103	116.7	117.8	+0.1	+0.1	24	50	119.5	11
500-544	523.4	358.1	142	112	123.4	125.0	+1.6	+1.3	27	55	131.25	10

TABLE VII

OCCIPITO-FRONTAL CIRCUMFERENCE OF HEAD (GLABELLA-INION)

.675 C.H.(mm) + 13.0 mm (367 cases)

Crown Heel Length (mm)		Crown Rump Length (mm)	Horizontal Head Circumference (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max.	Min	Mean (a)	Mean (b)	mm	Per cent		C.H. Length (cm)	Value (mm)	Per cent increment
25- 50	36.6	31.0	49	26	37.5	37.7	+0.2	+0.5	16	5	46.75	—
50-100	73.4	57.0	76	42	61.9	63.9	+2.0	+3.2	29	10	80.50	72
100-150	124.2	88.9	113	76	95.6	96.8	+1.2	+1.3	45	15	114.25	42
150-200	172.8	119.4	146	107	131.8	129.6	-2.2	-1.7	28	20	148.00	30
200-250	225.3	152.3	194	142	167.1	165.1	-2.0	-1.2	50	25	181.75	24
250-300	273.1	183.9	225	173	199.8	197.3	-2.5	-1.3	46	30	215.50	19
300-350	323.9	223.7	261	204	232.6	231.6	-1.0	-0.4	36	35	249.25	16
350-400	369.9	246.2	290	234	260.2	262.7	+2.5	+1.0	35	40	283.00	14
400-450	423.2	287.9	312	255	290.6	298.7	+8.1	+2.8	29	45	316.75	12
450-500	471.4	318.5	364	288	322.9	331.2	+8.3	+2.6	24	50	350.50	11
500-544	523.4	358.1	373	320	348.5	366.3	+17.8	+5.1	27	55	384.25	10

TABLE VIII

SUBOCCIPITO BREGMATIC CIRCUMFERENCE OF HEAD

.625 C.H.(mm) + 16.0 mm (365 cases)

Crown Heel Length (mm)		Crown Rump Length (mm)	Suboccipito Bregmatic Circumference (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated						
Range	Mean		Max	Min	Mean (a)	Mean (b)	mm	Per cent		C.H. Length (cm)	Value (mm)	Per cent increment
25- 50	36.6	31.0	48	28	37.4	38.9	+1.5	+4.0	16	5	47.25	—
50-100	73.4	57.0	76	41	61.7	63.1	+1.4	+2.3	29	10	78.50	66
100-150	124.1	88.8	110	75	94.6	93.6	-1.0	-1.1	44	15	109.75	40
150-200	172.8	119.4	140	100	124.0	124.0	0.0	0.0	28	20	141.00	28
200-250	225.3	152.3	184	130	160.2	156.8	-3.4	-2.1	52	25	172.25	22
250-300	273.5	184.1	210	161	191.3	186.9	-4.4	-2.3	45	30	203.50	18
300-350	323.9	223.7	247	195	222.2	218.4	-3.8	-1.7	36	35	234.75	15
350-400	369.9	246.2	251	221	248.3	247.2	-1.1	-0.4	35	40	266.00	13
400-450	423.2	287.9	291	246	273.2	280.5	+7.3	+2.7	29	45	297.25	12
450-500	471.4	318.5	352	282	303.8	310.6	+6.8	+2.2	24	50	328.50	11
500-544	523.4	358.1	347	308	336.3	343.1	+6.8	+2.1	27	55	359.75	10

TABLE IX
SUBOCCIPITO-FRONTAL CIRCUMFERENCE OF HEAD
·65 C.H. (mm) + 150 mm (366 cases)

Crown Heel Length (mm)		Crown Rump Length (mm)	Suboccipito-frontal Circumference (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)				C.H. Length (cm)	Value (mm)	Per cent increment
Range	Mean		Max.	Min.	Mean (a)		mm	Per cent				
23-50	36·6	31·0	50	28	39·0	38·8	-0·2	-0·5	16	5	47·5	—
50-100	75·4	57·0	78	45	62·9	64·0	+1·1	+1·7	29	10	80·0	68
100-150	124·2	88·9	115	73	96·8	95·7	-1·1	-1·1	45	15	112·5	41
150-200	172·8	119·4	143	111	132·7	127·3	-5·4	-4·1	28	20	145·0	29
200-250	225·3	152·3	192	141	166·5	161·4	-5·1	-3·1	52	25	177·5	22
250-300	273·5	184·1	224	170	197·7	192·8	-4·9	-2·5	45	30	210·0	18
300-350	323·9	223·7	257	201	227·8	225·5	-2·3	-1·0	36	35	242·5	15
350-400	369·9	248·2	284	225	254·5	255·4	+0·9	+0·4	35	40	275·0	13
400-450	423·2	287·9	300	248	280·3	290·1	+9·8	+3·5	29	45	307·5	12
450-500	471·4	318·5	354	280	312·3	321·4	+9·1	+2·9	24	50	340·0	11
500-544	523·4	356·1	367	319	338·9	355·2	+16·3	+4·8	27	55	372·5	10

TABLE X
OCCIPITO-MENTAL CIRCUMFERENCE OF HEAD (MENTON-INION)
·63 C.H. (mm) + 90 mm (355 cases)

Crown Heel Length (mm)		Crown Rump Length (mm)	Occipito-Mental Circumference (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)				C.H. Length (cm)	Value (mm)	Per cent increment
Range	Mean		Max.	Min.	Mean (a)		mm	Per cent				
23-50	35·9	30·5	47	23	33·4	31·6	-1·8	-5·4	15	5	40·5	—
50-100	75·4	57·0	73	40	53·6	56·5	+2·9	+5·4	29	10	72·0	78
100-150	123·5	88·4	101	63	83·5	86·8	+3·3	+4·0	43	15	103·5	44
150-200	172·8	119·4	135	95	117·5	117·9	+0·4	+0·3	28	20	135·0	30
200-250	225·3	152·3	181	125	156·0	150·9	-5·1	-3·3	50	25	166·5	23
250-300	273·1	183·9	217	162	186·6	181·1	-5·5	-2·9	46	30	198·0	19
300-350	323·9	223·7	257	190	219·8	213·1	-6·7	-3·0	36	35	229·5	16
350-400	369·9	248·2	279	213	245·9	242·0	-3·9	-1·6	35	40	261·0	14
400-450	423·5	288·1	297	230	270·9	275·8	+4·9	+1·8	28	45	292·5	12
450-500	471·5	318·3	367	269	308·4	306·0	-2·4	-0·8	23	50	324·0	11
500-544	525·3	356·4	380	307	336·2	339·9	+3·7	+1·1	22	55	355·5	9

TABLE XI
LARGE CIRCUMFERENCE OF HEAD (MENTON-LAMBDA)
·72 C.H. (mm) + 100 mm (343 cases)

Crown Heel Length (mm)		Crown Rump Length (mm)	Large Circumference (mm)				Difference between (a) and (b)		Number of cases	Calculated Values at 5cm Intervals of Crown Heel Length		
			Observed			Calculated Mean (b)				C.H. Length (cm)	Value (mm)	Per cent increment
Range	Mean		Max.	Min.	Mean (a)		mm	Per cent				
23-50	35·9	30·5	46	27	36·7	35·8	-0·9	-2·5	15	5	46·0	—
50-100	75·4	57·0	78	44	62·0	64·3	+2·3	+3·7	29	10	82·0	78
100-150	123·5	88·4	112	79	96·8	98·9	+2·1	+2·2	42	15	118·0	44
150-200	173·2	119·6	153	116	134·6	134·7	+0·1	+0·1	27	20	154·0	31
200-250	225·3	152·3	199	149	174·7	172·2	-2·5	-1·4	50	25	190·0	23
250-300	271·7	182·1	250	182	207·4	205·6	-1·8	-0·9	43	30	226·0	19
300-350	323·9	223·7	282	214	246·1	243·2	-2·9	-1·2	36	35	262·0	16
350-400	369·5	248·6	300	253	276·2	276·0	-0·2	-0·1	33	40	298·0	14
400-450	421·8	286·3	335	278	310·9	313·7	+2·8	+0·9	23	45	334·0	12
450-500	474·0	321·0	402	330	355·3	351·3	-4·0	-1·1	20	50	370·0	11
500-544	523·3	359·2	407	356	383·9	386·8	+2·9	+0·8	25	55	406·0	10

to make the sex indeterminate the symbol ⊗ was used. The grouping of the several points was so close that similar graphs of the other measurements were made, Figs. 2 to 6. In each one, the diameter, or circumference, under consideration was plotted as ordinate, against the crown heel (C. H) as abscissa, and the same plan of distinguishing sex was employed.

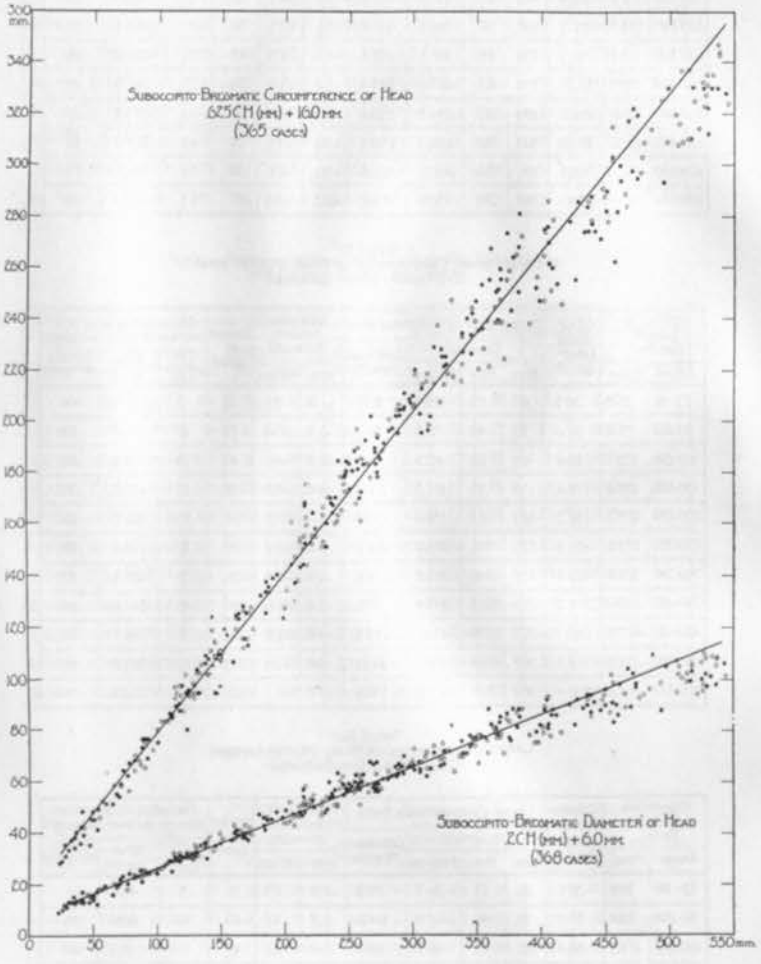

Fig. 3.

It was not at once evident which method of drawing the curves through these graphs would be the most satisfactory. Each of the three most common methods, not including inspection, namely, the weighted median, the weighted average, and the arithmetic average weighted by the median crown-heel height was tried, and equally

satisfactory curves resulted. The method of the averages* was chosen as being the one more commonly used, and, perhaps, the more readily comprehensible.

Fig. 7 with its solid line represents the field graph and resultant

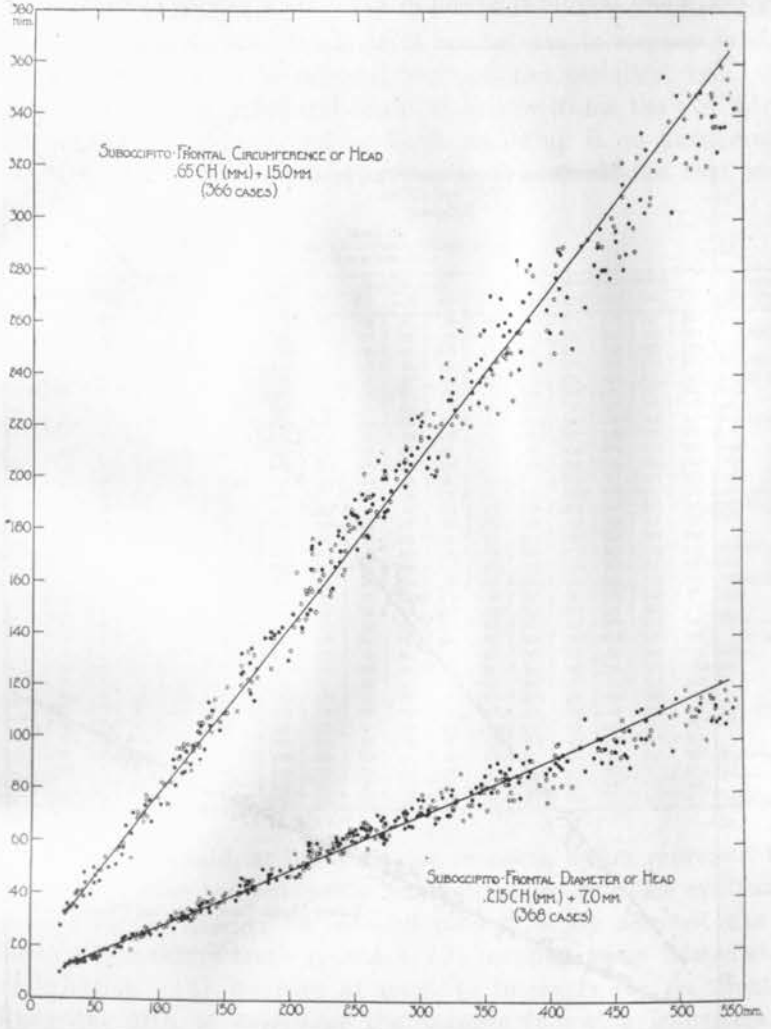

Fig. 4.

curve for the formalin preserved material, and, as such may be taken as quite representative of any series of Caucasian fetuses, similarly preserved. Similar curves resulted for the other measurements studied.

*The arithmetic average, for example, of the occipitofrontal diameters of the cases in each five centimeter interval was plotted against the arithmetic average of the crown heel lengths for the same cases. The curve was drawn through these resulting points.

The data for the plotting of these curves along with the range for the separate intervals, appears in columns 1 to 6 of Tables II to XI.

SUMMARY

These curves were quite striking in their characteristics. The curve for Fig. 5 and the upper graph in Fig. 6 were practically straight lines

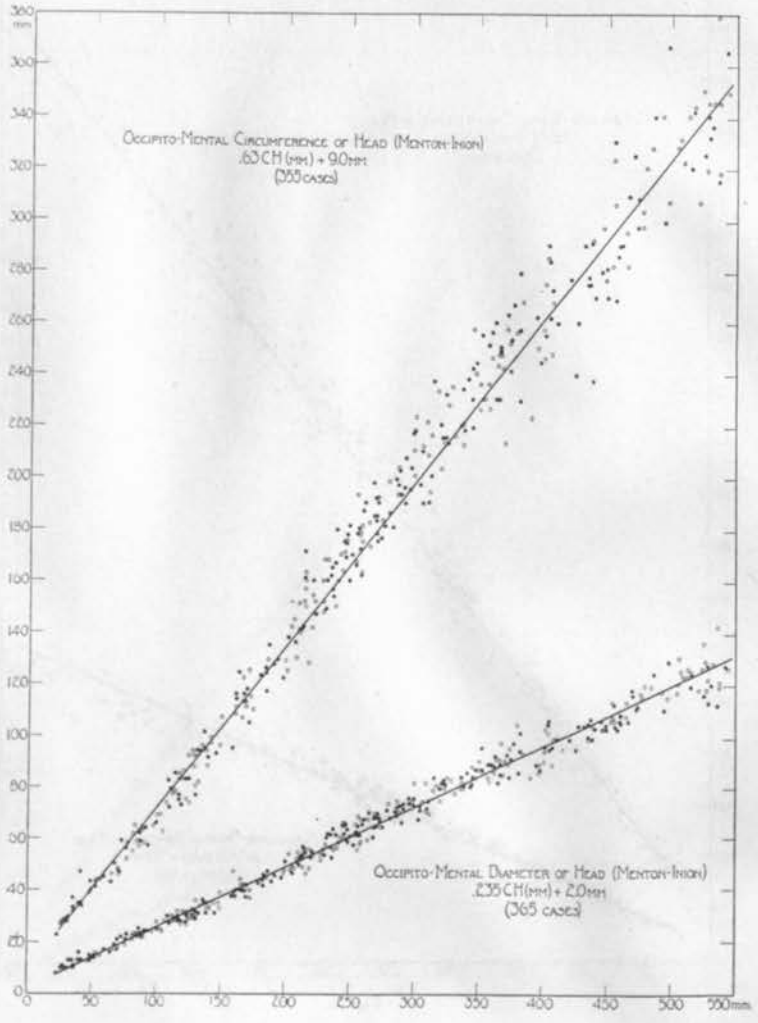

Fig. 5.

throughout. In Fig. 1 there resulted a straight line up to about 300 mm. standing height, at which point there was a deflection toward the vertical. The remaining curves were deflected downward at 300-350 mm. standing height from straight lines below that point. Feeling that these deflections might be artifacts, due to the type of

material, the writer undertook two other sets of investigations to determine:

1. The effects of preservation, as carried out on this material, and
2. The effects of birth moulding.

A chance observation of the injection process suggested the plan to be followed in the first of these two studies. Along with similar changes in the trunk, the cranial vault can be seen to increase in size, as one of these fetuses is injected through the umbilical vein. At the same time, and as a natural result of this swelling, the overriding of the cranial bones produced by birth moulding is, in part, eradicated. One might immediately arrive at the conclusion that such

TABLE XII
MEASUREMENTS OF UNMOULDED HEADS (MM)
(LIVING INFANTS)

Period of Development	Name	Sex	Age in Hours	Parity of Mother	Method of Delivery	Crown Heel Length	Head Diameters					Head Circumferences					Palpable Moulding
							OF	BP	SOB	SOF	OM	HHC	SOBC	SOFC	OMC	LC	
Premature	Be	M	29	?	S.	394	101	79	88	95	96	290	271	277	257	307	None
	Tib	M		?	Post.	396	96	77	88	89	95	272	256	266	246	289	- (Dead)
	Wi	M	28½	I	C.S.	470	111	90	100	103	106	326	305	310	283	330	-
	Br	F	1	VII	S.	475	116	88	96	106	115	324	295	315	295	335	very slight
	We	F	2	1	S.	475	112	87	97	102	100	320	297	307	277	330	Slight transverse
Mature	Pa	F	4	I	S.	480	118	89	95	103	115	338	306	312	310	345	None
	Es	M	6½	IV	C.S.	485	126	103	109	118	117	360	339	348	335	367	-
	McA	M	1½	?	S.	490	124	93	104	113	120	355	320	331	310	360	Slight ant-post
	Fl	F	25½	I	S.	490	122	91	99	110	111	338	307	319	291	355	Slight
	Ca	F	1½	V	S.	490	117	95	102	112	115	334	320	328	310	350	None
	Mo	M	3½	I	S.	490	124	93	105	114	121	361	324	331	280	360	Slight
	Br	M	7	II	C.S.	495	119	94	104	112	124	334	308	327	306	360	None
	Wo	M	3	I	S.	498	122	101	100	112	116	355	330	335	310	358	Slight ant-post
	Bra	M	½	I	S.	500	123	102	97	111	125	365	325	346	333	365	Little ant-post
	Se	F	2	I	S.	500	117	102	107	111	120	347	318	342	322	367	None
	OH	M	7½	V	S.	500	124	93	106	116	119	345	330	334	325	360	
	Oa	M	19½	I	S.	500	118	97	103	109	115	342	319	325	318	358	Slight ant-post
	Or	F	5	?	S.	500	123	101	108	110	125	353	322	328	312	362	None
	Sw	M	10	?	S.	505	114	97	104	112	114	343	326	328	312	354	Slight ant-post
	OC	M	1	II	S.	505	129	97	108	116	116	356	332	340	310	365	None
	Su	F	6½	?	S.	506	125	98	106	122	127	363	339	355	348	377	
	Al	M	6½	IV	S.(t)	510	121	92	105	115	113	347	327	335	302	342	Slight transverse
	As	M	1½	II	S.	510	123	101	102	111	125	358	330	338	335	379	ant-post
	Cl	F	13	I	S.(t)	510	125	98	102	114	121	347	317	335	310	355	None
	Ba	M	23	?	S.(t)	515	128	100	114	120	120	366	342	351	320	373	-
	Fe	F	¾	VI	S.	515	121	98	103	114	120	352	327	340	310	362	-
	Do	M	6½	III	C.S.	520	120	101	104	113	124	357	347	354	305	360	-
	Il	M	4	VI	S.	520	117	102	108	113	115	354	340	348	327	363	Slight ant-post
	En	M	2	I	S.	520	115	91	100	110	116	330	318	325	312	350	None
	Wo	M	21½	V	S.	525	116	94	100	112	117	339	323	334	317	357	
	Ki	M	3½	I	S.	528	132	104	110	115	123	375	345	348	332	384	Slight ant-post
	Gra	F	14	I	S.	535	137	106	119	127	126	385	367	373	320	400	
Average Newborn			6¾			505	122	97	105	114	119	352	328	337	316	368	
Postmature	Re	M	7½	I	S.	570	134	103	109	117	125	365	341	355	322	385	Moderate ant-post

injected fetuses would, at least in some respects, better represent the fetus *in utero* than the uninjected newborn material. This eventually proved to be the case. The detailed plan of study adopted was as follows: (1) measure fresh specimen; (2) measure again immediately after injection. (3) measure at monthly intervals for six months, omitting the fifth, to determine the changes following immersion in formalin. For the smaller fetuses which were not primarily injected, items 1 and 3 were carried out in a similar manner. The results obtained in this latter study on the uninjected specimens were quite significant. For the various measurements the averages obtained are shown in Table XIII.

Preservation by the immersion in formalin alone effects but little change in the dimensions under consideration. The changes noted

are each well within the limit of error in measuring those diameters and can therefore be neglected as far as correcting the curves in Figs. 1 to 6 is concerned. This is particularly true since the size of specimen seemed to bear no relation to the percentage change which oc-

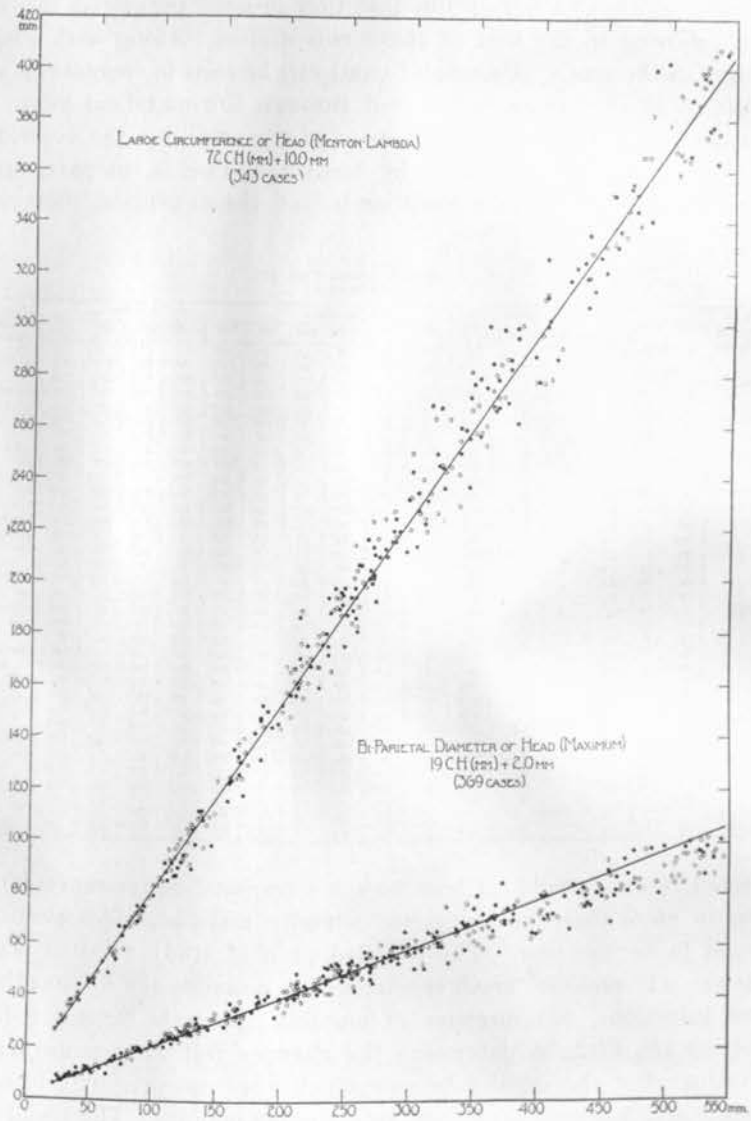

Fig. 6.

curred in that specimen. Only ten fetuses were so studied; but, in view of the almost negative results, such a number of cases is probably sufficient for all practical purposes.

Primary injection, on the other hand, produces a much more notice-

TABLE XIII

	AVERAGE FRESH (MM).	AVERAGE END 6 MOS. (MM)	AVERAGE PER CENT CHANGE
C H	263	261	− 0.8
C R	178	178	− 0.4
O F	65	65	− 1.0
Bi P	49	48	− 0.9
So B	59	60	+ 0.4
S O F	63	64	+ 0.7
O M	62	62	+ 0.1
H H C	183	186	+ 1.4
S O B C	181	184	+ 1.6
S O F C	174	179	+ 2.5
O M C	172	174	+ 1.2
L C	190	190	− 0.3

able change. Here again the immersion, following the injection, produces but little effect. Twenty-six specimens were employed in this study and individual variation, while slightly more marked, was due more to the amount of fluid injected than to any other factor. About 20 per cent of body weight seems to be the optimum amount of fluid to use. The size of the specimens seems to make little, if any, difference in the amount of percentage change produced in the head measurements except that the previous condition, in utero, seems to act as a sort of natural limit to the swelling process. The results of this study are shown in Table XIV.

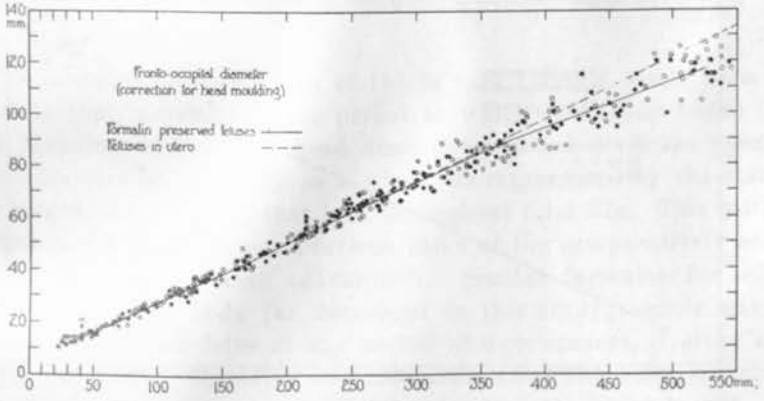

Fig. 7.

While these results show essentially negative changes for body length, they are distinctly positive for the head measurements. If the resulting correction be applied to the original curves for Figs. 1 to 6, the resulting curves would occupy the position shown by the dotted line in Fig. 8. Such a set of curves would properly represent the head proportions for one or several stillborn fetuses.

This injection and preservation study revealed another fact of importance, namely, a peculiar edematous swelling of the tissues of

TABLE XIV

	PERCENTAGE CHANGE FROM INJECTION	PERCENTAGE CHANGE AT END OF 6 MOS. PRESERVATION
C H	+ 1.2	+ 0.8
C R	+ 1.6	+ 0.5
O F	+ 2.6	+ 2.6
Bi P	+ 4.4	+ 3.9
S O B	+ 3.8	+ 3.9
S O F	+ 4.3	+ 4.9
O M	+ 4.8	+ 2.9
H H C	+ 3.8	+ 4.5
S O B C	+ 4.6	+ 4.8
S O F C	+ 5.1	+ 6.1
O M C	+ 7.7	+ 7.4
L C	+ 5.4	+ 5.0

the ischiorectal fossa with a consequent protrusion of the perineum. This protrusion was found to account for the upward deflection in Fig. 1 because the crown-rump measurement had been taken to the perineal surface instead of to the tubera ischii and a technical error thereby introduced. When properly corrected this curve resulted in a straight line, indicated by the straight line in Fig. 1. The fact that injected specimens, in which the effects of birth moulding have been totally or partially obliterated, approach very much more closely to

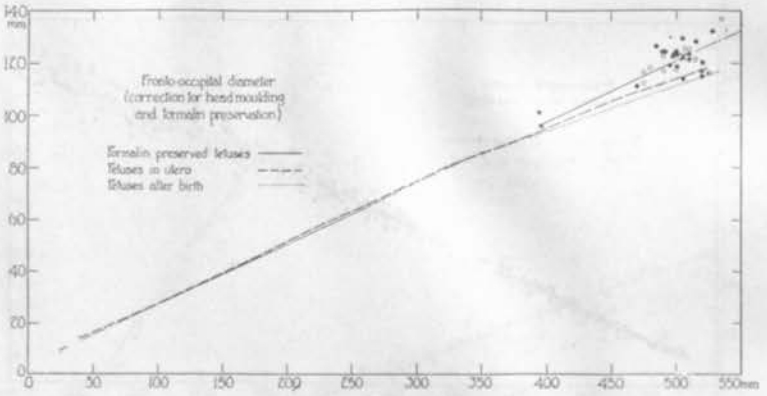

Fig. 8.

a central, straight line than do fresh, stillborn fetuses, suggested the above mentioned study of unmoulded heads. For this purpose babies born by cesarean section, elective, or very early after the initiation of pains, and those born by breech extraction were utilized. Of the total number of these cases (33), twenty-seven were selected as representing full term infants, they having been born within two weeks of term, according to the menstrual history.

The separate readings of this series of measurements appears in

Table XII. These measurements, plotted by the same method outlined above, all fall well above the curve for preserved material (Fig. 8). In fact the average point* of the 27 selected cases, in the case of each dimension, falls directly (within 1 mm.) in the continuation of the lower straight portion of the curve (broken line Fig. 7 and solid line Fig. 8). We have then, by the removal of artifacts, found that all these "curves" are straight lines. These straight lines are shown collectively in Fig. 9 and individually in relation to the field graphs of preserved material in Figs. 1 to 6 inclusive. This would indicate that the fetal head, in relation to body length, has a perfectly definite rate of growth throughout fetal, not including embryonic, life.

These curves, being straight lines, can be expressed by the formula: $y=ax+b$ where (y) is any given measurement, (x) the standing height, and (a) and (b) are constants. For the various measurements these formulae are:

Sitting height	.66	(C H)	+ 5.0 mm
Occipito-Frontal Diameter	.235	"	+ 4.0 "
Biparietal "	.19	"	+ 2.0 "
Suboccipito-Bregmatic "	.2	"	+ 6.0 "
Suboccipito-Frontal "	.215	"	+ 7.0 "
Occipito-Mental "	.235	"	+ 2.0 "
Horizontal Head Circumference	.675	"	+ 13.0 "
Suboccipito-Bregmatic "	.625	"	+ 16.0 "
Suboccipito-Frontal "	.65	"	+ 15.0 "
Occipito-Mental "	.63	"	+ 9.0 "
Large "	.72	"	+ 10.0 "

The constant positive value of (b) in each formula would seem to indicate that, previous to the period at which this study began (23 mm. standing height), the head dimensions gained a certain number of millimeters on the body as a whole, as represented by the standing height, and retained that lead throughout fetal life. This mathematically substantiates our previous ideas of the comparatively early development of the head (Jackson[24]). Similar formulae for other dimensions of the body (as developed in this study) enable one to construct an entire fetus at any period of development, if given any single dimension. Moreover any measurement of the body is just as valuable in determining age as is the standing or sitting height.

From the practical standpoint, one may arrive at the size of the fetal head *in utero* if he can accurately determine the size of any dimension of the body. A moderate number of clinical demonstrations of this indirect method of mensuration have been made and a definite x-ray technic is being developed for this purpose at the present time. Further descriptions of the details of the technic employed and the

*The average values of fetal head measurements *in utero* present a rather new idea of the size and proportions of the obstetric passenger and are probably of more clinical importance, in some respects, than the postnatal values quoted in the text-books.

results obtained will be given when a conclusive series of measurements has been completed.

SUMMARY AND CONCLUSIONS

1. Measurements of the head, *in utero*, plotted as ordinates against standing heights as abscissae for any group of Caucasian fetuses, result

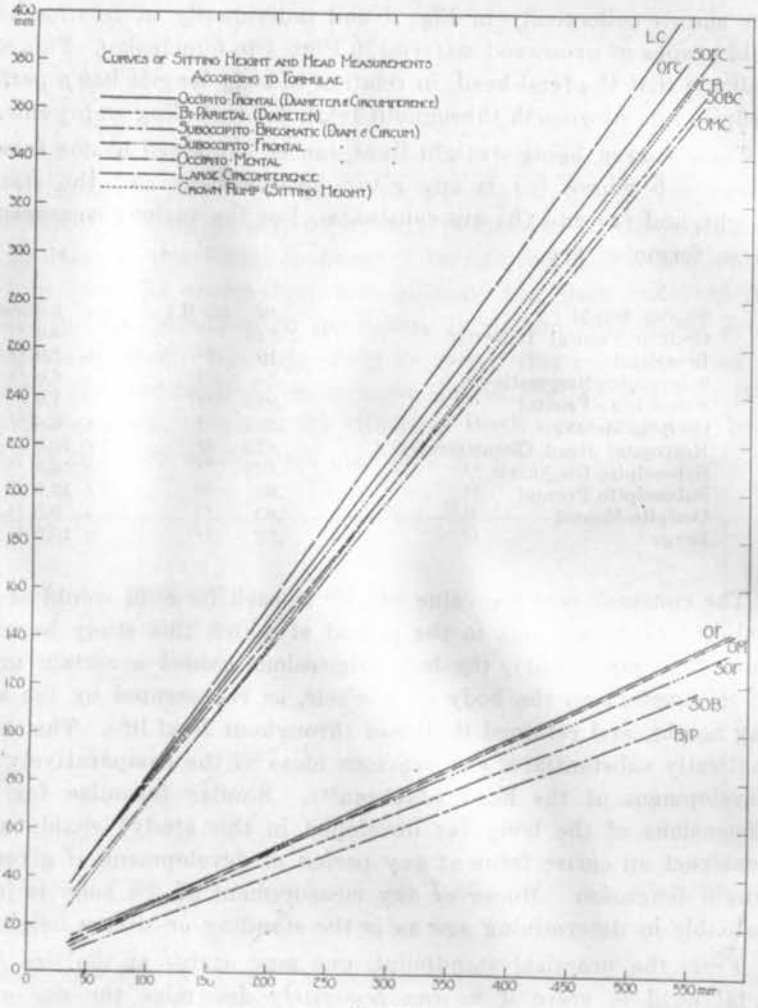

Fig. 9.

in straight line curves. (This is also true of measurements of other parts of the body.)

2. The relationship between any two dimensions can, then, be expressed by the straight-line, empirical formula: $y = ax \pm b$, (x) and (y) being body dimensions, and (a) and (b) constants.

3. By study of these formulae we find definite mathematical proof of development in the cephalocaudad direction during embryonic life and,

4. A definite rate of growth, in any dimension, established by the third month and maintained throughout the remainder of prenatal life.

5. By the aid of these formulae, one may accurately construct the external body proportions of a fetus at any period of development, if given any single dimension.

6. Likewise, one may deduce the size of the head if one can accurately determine any body measurement *in utero*. A definite technic for this indirect intrauterine cephalometry is worthy of prolonged intensive study. By such a method one could solve problems of disproportion between passage and passenger, as well as determine viability and maturity with a considerable degree of accuracy.

7. Birth moulding probably effects greater changes in head dimensions than ordinarily thought.

8. Fetuses preserved in formalin, by the method outlined, better represent the living fetus *in utero* than any other available type of material.

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